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# CRUISE MISSILES FOR THE U. S. NAVY: AN EXEMPLAR OF INNOVATION IN A MILITARY ORGANIZATION

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THE NATURE OF WAR AT SEA HAS CHANGED THROUGH TIME AS A DIRECT CONSEQUENCE OF INNOVATIONS IN TECHNOLOGY, TACTICS AND OPERATIONAL ART, AND NAVAL ORGANIZATION. SUCCESS IN FUTURE CONFLICTS WILL DEPEND UPON THE NAVY'S ABILITY TO ACQUIRE APPROPRIATE NEW TECHNOLOGIES AND TO INTEGRATE THAT TECHNOLOGY INTO FUTURE FORCES. SENIOR NAVAL OFFICERS AND HISTORIANS HAVE IDENTIFIED CRUISE MISSILE TECHNOLOGY AS AN AREA WHERE THE NAVY RESISTED INNOVATION, A FAILURE THAT WAS BLAMED ON INTRA-SERVICE POLITICAL IMPERATIVES. EXAMINATION OF THE HISTORY OF CRUISE MISSILE INNOVATION REVEALS A VERY DIFFERENT PATTERN. OVER THE PAST FIFTY YEARS, THE NAVY PERSISTENTLY PURSUED THE DEVELOPMENT OF CRUISE MISSILE TECHNOLOGY. THE SINGLE SIGNIFICANT GAP IN CRUISE MISSILE DEVELOPMENT IN THE PAST HALF CENTURY, 1959-1967, RESULTED FROM UNIQUE HISTORICAL CIRCUMSTANCES OF THE TIME, AND NOT ORGANIZATIONAL ANTIPATHY TOWARD CRUISE MISSSILES. SEVERAL LESSONS EMERGE FROM THE HISTORY OF NAVAL CRUISE MISSILE INNOVATION. PROSPECTS FOR SUCCESS IN FUTURE INNOVATIVE ENDEAVORS CAN BE ENHANCED BY PROVIDING STABLE AND AMPLE RESOURCES TO PROJECT SCIENTISTS AND ENGINEERS. MANY EFFORTS TO INNOVATE END IN

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## EXECUTIVE SUMMARY

The nature of maritime warfare has changed through time as a consequence of the introduction of new weapons and other technologies, changing tactics and operational art, and new naval organizations. The character of future conflicts will undoubtedly differ from today's warfare, although the direction and extent of future change is difficult to predict. The U. S. Navy's success in future combat depends upon its ability to acquire appropriate new technologies and to integrate those technologies into its future force structure. This project was undertaken to examine the historical record of the Navy's efforts to innovate in a limited field of weapons development: naval cruise missiles.

Historians and at least one retired admiral have repeatedly criticized the U. S. Navy for its apparently belated attempts to develop a cruise missile. The delay has been blamed on naval aviators, who allegedly viewed the cruise missile as a potential threat to manned aircraft and, indirectly, the political position of aviators within the Navy. The retarded acquisition of cruise missiles (Harpoon and Tomahawk) resulted, in this view, from intra-service political maneuvering between the major warfare communities.

An examination of the history of naval cruise missile innovation demonstrates that, over the past 50 years, the Navy persistently pursued the development of cruise missile technology. The single interruption in cruise missile innovation, 1959-1967, resulted from extreme budgetary pressures and conflicting organizational priorities. While certain naval aviators indeed opposed the development of cruise missile technology, the facile historical interpretation of aviators opposing cruise missile

innovation is not correct. Rather, the Navy has demonstrated a long interest in cruise missiles and undertook to acquire anti-ship missiles when the circumstances of mission and technology were finally right.

Several lessons emerge from the history of Naval cruise missile innovation. The objectives of long-range technological innovation will probably be controversial. Leaders must be prepared to proceed in the face of well-intentioned opposition. Most innovative efforts end in failure; senior naval and government officials must expect and accept frequent failure as a cost of innovation. The prospects for success in future endeavors can be enhanced by providing steady and ample resources to projects. Naval leadership must guard against prematurely rushing new systems into operational evaluation or production. In deciding the future of ongoing projects, leaders should avoid the organizational myopia that results from judging future systems on the basis of today's needs. Finally, the Navy needs officers who are willing to promote new technologies: the zealots who crusade for their vision of future warfare and the technologies necessary for their vision. These zealots initiate the political process that leads to organizational innovation, and are a critical component of that innovation process.

# PREFACE

This Advanced Research Project is an expansion of research that was initially presented in a paper for the National Security Decision Making Course at the Naval War College. That paper, entitled "Technological Innovation in Naval Force Planning: Obstacles and Opportunities," was submitted to Professor Mackubin T. ("Mac") Owens in October, 1993. Professor Owens suggested that the original project might be expanded into an Advanced Research Project and offered to act as advisor for the project. To our surprise, the research reported here gradually forced a thorough rethinking and, eventually, rejection of the conclusions presented in the earlier paper.

One objective of this project was to prepare an unclassified paper that might be published, if the results merited such attention. Consequently, a considerable body of literature on the Harpoon and Tomahawk missile systems was not incorporated into this paper. In fact, the outlines of those programs are clear even if the details remain classified. Moreover, it is the earlier and less well known programs, when the Navy was supposedly ignoring cruise missile technology, that required a more thorough treatment.

Professors J. B. Hattendorf and M. T. Owens and Lieutenant Commander J. T. Dunigan kindly criticized earlier drafts of the manuscript and suggested numerous improvements. Any remaining errors of fact or analysis are my own.

## PREFATORY NOTES ON MISSILE TERMINOLOGY

There is a bewildering variety of terms for the various types of unmanned aircraft and missiles developed in this century. The terminology is often contradictory. For example, different authors define a cruise missile in a variety of ways, although most authors agree that a cruise missile relies upon aerodynamic lift during flight. However, some specify that cruise missiles have air-breathing engines.[1] Jane's Naval Weapons Systems takes the alternative view and defines the cruise missile solely on the criterion of an air-breathing motor.[2] Other authors include an extended range in their definition. For example, the Oxford English Dictionary defines cruise missile as a ". . . guided pilotless jet aircraft carrying a warhead," apparently excluding the possibility of a piston-driven cruise missile.[3] In order to simplify this terminological confusion, the following definitions are employed in this paper:

Ballistic Missile: A missile that does not rely upon aerodynamic lift during flight and that has an entirely self-contained (rocket) propulsion system.

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[1] K. Tsipis, "Cruise Missiles," Scientific American, vol. 236, no. 2 (February 1977), p. 20; J. C. Toomay, "Technical Characteristics," R. K. Betts, ed., Cruise Missiles: Technology, Strategy, Politics (Washington D.C: The Brookings Institution, 1982); R. Huisken, The Origin of the Strategic Cruise Missile (New York: Praeger, 1981).

[2] E. R. Hooten, ed., Jane's Naval Weapons Systems, 1989 (Surrey: Jane's Defense Data, 1989) Jane's does not number the pages in this unbound collection of pages. The cited information comes from the article on the RGM/UGM-109B/C Tomahawk. The page is labeled: JNWS-ISSUE 11.

[3] J. A. Simpson and E. S. C. Weiner, preparers, The Oxford English Dictionary, 2nd ed., (Oxford: Clarendon Press, 1989), vol. IV, p. 80.

Cruise Missile: An unmanned missile that relies upon aerodynamic lift (it flies) and requires oxygen for its engine (it "breathes").

Glide Bomb: An aerially delivered, guided weapon that lacks any propulsion system. "Walleye" and the World War II vintage "Glomb" were examples of glide bombs.

For example, some do not consider the well-known Harpoon SSM to be a cruise missile, as it lacks aerodynamic surfaces or wings. The Tomahawk series of missiles (TASM, TLAM-C, TLAM-D, TLAM-N), on the other hand, are cruise missiles because they employ aerodynamic lift and require oxygen for their turbofan engines. Aircraft that were designed and constructed as manned vehicles, but were subsequently refitted as attack drones and offensive drone aircraft, meet the definition of cruise missiles. Remotely piloted vehicles (RPV) that are employed offensively are usually (but not always) cruise missiles. The term "guided missile" has ceased to be useful, because it does not distinguish between externally and internally controlled missiles and because virtually none of these systems is truly "unguided." Consequently, the term will be avoided in this paper.

Clearly, these definitions do not cover the entire realm of possible missile configurations (a non-aerodynamic, air-breathing missile, for example). And, to a certain extent, the definitions necessarily intergrade. For example, Germany's World War II vintage glide bomb, the HS 293, had a rocket booster that burned for the first 10 seconds of the glide bomb's flight.[4] Nevertheless, they are sufficient for the purposes of the discussion to follow, and will be employed in this paper.

[4] H. A. Wagner, "Guidance and Control of the Henschel Missiles," T. Beneke and A. W. Quick, eds., History of German Guided Missiles Development, (Brunswick: Verlag E. Appelhans and Company, 1957), p. 11.

TABLE ONE

MISSILE CLASSIFICATION

| TYPE | AERODYNAMIC LIFT | PROPULSION |
|---|---|---|
| Cruise Missile | Yes | Air Breather |
| Ballistic Missile | No | Rocket |
| Glide Bomb | Yes | None |

[Source: Author]

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# CHAPTER I

## INTRODUCTION AND OBJECTIVES

Many students of warfare view innovation as the key to major shifts in military power through the course of human history.[1] Such innovations can take a number of forms, including technology, new tactics, operational art or strategy, or new organization. The importance of innovation is self-evident from the history of conflict: war is different now from 1917, 1941, 1950, or 1964. From this observation we can surmise with reasonable confidence that war will also be different in the future. The task before us is to ensure that appropriate technologies will be in place when they are needed.

This study examines the history of cruise missile programs in the U.S. Navy in order to understand the events and processes that inhibited or facilitated, however haltingly, the development of the Sea-Launched Cruise Missile (SLCM). The purpose for undertaking the study is to evaluate the Navy's efforts in technological innovation in one narrow field of endeavor. If the innovation process in this field was healthy, it will be possible to correct some false historical impressions. Alternatively, if shortcomings existed, they can be identified and possible corrective actions proposed for managing technological innovation in the future. The U.S. Navy's future success or failure will depend heavily on the dynamics of its innovative activity. It is important to understand the process, and the potential impediments, in order to facilitate future innovation.

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[1] M. van Creveld, Technology and War: From 2000 BC to the Present (London: Brassey's (UK), 1991); J. Keegan, A History of Warfare (New York: Alfred A. Knopf, 1993). S. P. Rosen, "New Ways of War: Understanding Military Innovation," International Security, vol. 13, no. 1 (Summer 1988), p. 134.

# CHAPTER II

## THE CRUISE MISSILE CHALLENGE

"The greatest single hurdle which all new weapons must overcome
is that of flaccid intolerance and clammy complacency
in the minds of those in high places in the military hierarchy.
This uncompromising vested stand for weapons that 'served me well
in my last campaign' has been with us since the earliest days of history."[1]

On the afternoon of 22 October, 1967, the Israeli destroyer Eilat was steaming approximately 13 miles off the coast of Egypt, near Port Said.[2] Her lookouts reported two Soviet-made Styx cruise missiles inbound at a range of nearly 6 miles, launched by Egyptian Komar-class missile boats anchored in Port Said. The Eilat maneuvered to elude the missiles but was unable to avoid them; both missiles struck the Israeli destroyer. The Eilat's crew attempted to save the ship and might have succeeded, had not two additional Styx missiles hit the ship approximately 90 minutes later. The ship was sinking as the fourth missile struck.

The fate of the Eilat caused consternation and concern among naval leaders throughout the world. This was the first loss of a battle-ready warship to a cruise missile

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[1] D. S. Fahrney, "The History of Pilotless Aircraft and Guided Missiles," Unpublished Manuscript, Naval Historical Center, 1958, p. 1366.

[2] R. C. Colvin, "Aftermath of the Elath," U. S. Naval Institute Proceedings, vol. 95, no. 10 (October 1969), p. 60.

attack. The Eilat, formerly HMS Zealous, was a veteran of World War II.[3] Although she was more than 20 years old, the Eilat was in good condition, manned by a capable crew, and prepared for battle when she entered her final engagement.[4] Nevertheless, the Eilat proved unable to defend herself against cruise missiles or to survive the attack. This incident demonstrated that cruise missiles were highly effective weapons against warships in wartime conditions. Subsequently, damage inflicted by cruise missiles on the Pakistani (1971) and British (1982) navies have added to the growing concern over these weapons.[5]

Following the Eilat incident, one could no longer doubt the effectiveness of relatively inexpensive cruise missiles launched from patrol craft or small combatants. Many of the cruise missiles available in 1967 could also be launched from aircraft. The lethality and range of cruise missiles changed the dimensions of warfare at sea. More importantly, sea control was no longer the sole domain of the aircraft carrier. Cruise missiles could provide an alternative means of achieving (at least local) sea control.

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[3] According to Jane's Fighting Ships 1966-67, HMS Zealous was launched in 1944 as part of Great Britain's wartime shipbuilding effort and was transferred to Israel in 1956. She displaced 1,700 tons and had a compliment of 250 officers and men.

[4] Colvin, "Aftermath," p. 62.

[5] W. J. Ruhe, "Cruise Missile: The Ship Killer," U. S. Naval Institute Proceedings, vol. 102, no. 5 (June 1976), p. 46; S. Woodward, One Hundred Days (Annapolis: Naval Institute Press, 1992), p. 223.

## Sea Control in the Twentieth Century

From the beginning of the 20th Century to the end of 1941, the Dreadnought defined the nature of battle at sea. Various fleet exercises prior to the outbreak of World War II demonstrated the potential striking power of the aircraft carrier, but it took the attack at Pearl Harbor (7 December 1941) and the battles of Coral Sea (7-8 May 1942) and Midway (4 June 1942) to establish that the carrier had become the dominant naval unit. The sinking of the Eilat appeared, at least to some, to signal another revolution in warfare at sea, away from the large and expensive carriers and toward small, inexpensive units capable of launching anti-ship missiles. At the very least, the United States Navy needed the means to counter Surface to Surface Missiles (SSMs). More importantly, the Navy needed to abandon its quarter-century of total reliance upon carriers and to develop its own cruise missiles.

The aircraft carrier has continued to dominate maritime warfare since the Second World War. But aircraft carriers, together with their embarked aircraft and escorts, are extremely costly defense systems. Even the United States, as the strongest national economy, could only sustain 16 carrier battle groups by the middle of the 1960s, a number that has grown steadily smaller in the 1990s. This expense put sea control beyond the reach of most nations. The advent of the surface-launched cruise missile, such as the Styx, offered less wealthy nations access to an inexpensive, yet effective, weapons system that could threaten even the carrier battle group. Furthermore, air-launched anti-ship missiles were developed simultaneously, giving economically weak nations the capacity to defend their shores from enemy fleets even in the total absence of warships. Cruise missiles brought sea control into the price range of less developed nations.

Cruise missiles were not a new concept; the SS-N-2A Styx cruise missile first became operational in 1959.[6] At the time the Eilat was lost, a number of countries had either received cruise missiles from the Soviet Union or were developing ship-launched anti-ship (SSM) or land to ship missiles. Among these were China (HY-1 Silkworm), Norway (Penguin), France (Exocet), Sweden (Rb 08A), and Israel (Gabriel).[7] More than a dozen countries had either deployed or were developing air-launched anti-ship missiles. Several countries were also developing defensive systems that might be effective against cruise missiles.

United States Navy in 1967. In the year the Eilat sank, the United States Navy had no SSM deployed or even under development. Furthermore, the Navy had only limited means to counter cruise missiles that might be launched against surface ships. This was surprising, given the wide deployment of Soviet SSMs within their fleet and the distribution of missiles to a number of Soviet client states, although the U.S. Navy was only just beginning to take the Soviet naval threat seriously. Nevertheless, U.S. Navy planners had encountered this problem earlier. During the Cuban missile crisis (October 1962), the presence of Cuban patrol craft armed with Styx missiles had been considered a threat to units of the U. S. naval blockade. The CIA had reported twelve Komar-class

[6] Jane's Weapons Systems 1987-8 (London: Jane's Publishing Company, 1988), p. 483.

[7] N. Friedman, The Naval Institute Guide to World Naval Weapons Systems (Annapolis: Naval Institute Press, 1989).

patrol boats armed with SS-N-2 Styx missiles in Cuban ports. In addition, Cuba was reported to have three cruise missile stations for coastal defense.[8] In that confrontation, the Navy's response to the problem of cruise missiles and shore-based aviation was to set the blockade far offshore, outside the range of both.[9] Naval defense against SSM depended in large part upon long-range strikes against potential launchers ("kill the archer"). With the sinking of the Eilat, it became clear that cruise missiles posed a serious threat to the U.S. Navy; one that had to be addressed more directly.

Soviet Union leadership in cruise missiles. At this point, it is instructive to compare force structure with the U.S. Navy's emerging rival, the Navy of the Soviet Union. In contrast to the U.S. Navy's focus on the aircraft carrier, the Soviet Union concentrated on the development of submarines and small combatants armed with cruise missiles. The USSR was the first nation to deploy an anti-ship SSM, the SS-N-1 Scrubber. Often named the Strela, the SS-N-1 was deployed in 1959 in Kildin-class destroyers.[10] The SS-N-2A Styx missile was deployed shortly thereafter, with more capable versions following later (2B in 1964, 2C in 1967). The Styx was intended for deployment in small patrol craft. The passing years have seen the continued addition of powerful new SSMs to the Soviet arsenal and the ongoing improvement of older missiles (see Table 2).

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[8] M. S. McAuliffe, ed., CIA Documents on the Cuban Missile Crisis, 1962 (Washington D.C: Central Intelligence Agency, 1992), p. 213.

[9] G. T. Allison, Essence of a Decision: Explaining the Cuban Missile Crisis (Boston: Little, Brown and Company, 1971), p. 127.

[10] N. Polmar, Guide to the Soviet Navy, 4th ed., (Annapolis: Naval Institute Press, 1986), p. 426.

## TABLE TWO

## SOVIET SURFACE TO SURFACE CRUISE MISSILES

| Missile | Name | Deployed | Range (NM) | Launcher |
|---|---|---|---|---|
| SS-N-1 | Scrubber | 1959 | 100 | Ships |
| SS-N-2a | Styx | 1959 | 25 | Patrol Boats |
| SS-N-2b | | 1964 | 27 | |
| SS-N-2c | | 1967 | 45 | |
| SS-N-3a | Shaddock | 1962 | 250 | Ships, submarines |
| SS-N-3b | | 1962 | 250 | |
| SS-N-3c | | 1960 | 400+ | |
| SS-N-7 | Starbright | 1968 | 35 | Submarine |
| SS-N-9 | Siren | 1969 | 60 | Submarine, PBs |
| SS-N-12 | Sandbox | 1973 | 300 | Ships, submarines |
| SS-N-14 | Silex | 1969 | 30 | Ships |
| SS-N-15 | Starfish | 1972 | 20 | Submarines |
| SS-N-16 | Stallion | 1972 | 50 | Submarines |
| SS-N-19 | Shipwreck | 1981 | 300 | Ships, submarines |
| SS-N-22 | Sunburn | 1981 | 60 | Ships |

Note: SS-N-1, 2, 3, 7, 12, 19, 22 are anti-ship weapons. SS-N-9, 14, 15, 16 are ASW weapons.

[Sources: Data from Polmar 1986 and Friedman 1989. Polmar gives the name of the SS-N-7 as Siren and gives no designation for the SS-N-9 missile.]

The Soviet investment in cruise missile technology can be best understood in the light of their overall naval objectives in the event of war. Initially, the Soviet Union's naval objectives were "...to help isolate the potential European battlefield from the vast resources of the United States...".[11] The Soviet Navy's mission was to prevent NATO from establishing and maintaining the sea control necessary for the reenforcement and resupply of Europe. Thus, the Soviet Navy's role was restricted to interdiction of resupply routes in the event of a major war in Europe. Air- and surface-launched anti-ship cruise missiles were a relatively inexpensive means of accomplishing that goal. Subsequently, the role for the Soviet Navy was expanded to include power projection and limited warfare in the third world.[12] In the event of a conflict in the Mediterranean or some other vital area, the Soviets believed that SSMs would counter the American advantage in carrier-launched aviation.

The subsequent Soviet investment in aircraft carriers reflected that nation's changing strategic interests. Construction of their three Kiev-class carriers and the Admiral Gorshkov, all apparently designed to operate helicopters and Forger VSTOL aircraft, together with the subsequent two Kuznetsov-class carriers were intended to enhance flexibility and force projection beyond the coastal waters of the U.S.S.R. by adding manned aircraft to the Soviet fleet.[13] With the arrival of aircraft carriers, the

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[11] N. Polmar, Soviet Naval Power: Challenge for the 1970's, (New York: Strategy Information Center, 1972), p. 33.

[12] Polmar, Soviet Naval Power, p. 37.

[13] J. S. Breemer, "The New Soviet Aircraft Carriers," U. S. Naval Institute Proceedings, vol. 107, no. 8 (August 1981), p. 31.

Soviet Navy has emerged as a legitimate competitor for sea control. Nevertheless, the primary role of the cruise missile in Soviet naval planning has apparently not changed.

## The Inevitability of Change

None of the weapons available in 17th, 18th, or even 19th centuries remain effective in the modern theater of war. The musket has been replaced by the assault rifle and the stealthy B-2 has superseded the biplane. The weapons of 1994 will also become obsolete, given the application of human ingenuity, money, and technology over time. Change, therefore, is critical for survival in the modern world. Successful innovation will play a crucial role in the long-term survival of military organizations and the polities they support and protect.

Unfortunately, change is difficult, both for individuals and organizations. People cherish stability and order in their lives. Bureaucracies encourage and reward uniformity; dramatic departures from the norm are usually met with skepticism, resistance, and even hostility. Among organizations, the military holds the reputation as one of the most rigid and staid bureaucracies known to man.

There are several explanations for this phenomenon. The most benign explanation is that the very nature of bureaucracy tends to frustrate innovation.[14] In this view, bureaucracies are designed to perform routine, repetitious tasks with minimum errors. Creativity has no place in such organizations. Martin van Creveld suggested that military

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[14] S. P. Rosen, Winning the Next War: Innovation and the Modern Military (Ithaca: Cornell University Press, 1991), p. 2; W. R. Farrell, "Bureaucracy is not a four letter word," Naval War College Review, vol. 40, no. 2 (Spring, 1987) p. 84.

organizations tend to be conservative for several reasons.[15] The leadership can fail to appreciate the value of specific technologies. Organizations might also have difficulty deciding which technologies might prove fruitful in the long term. Such decisions require the ability to foresee the nature of future wars.

Stanley Sandler suggested that several psychological and organizational phenomena hamper military innovation. The recent addition of new technology could actually limit a military organization's ability to absorb still newer weapons, because the technology and people who manage it are so recently arrived. Naval leaders, who have seen many technologies touted as "the answer" to the Navy's problems, are understandable skeptical of <u>any</u> innovation. Also, warfighters are inherently reluctant to promote complex technology, preferring simple systems wherever possible. Sandler offers no prescription for facilitating innovation, but warns against simplistic interpretations of organizational difficulties in innovation.[16]

The hypothesis advanced by Vincent Davis is less benign; the political imperatives of groups within the military frequently obstruct innovation.[17] Ronald J. Kurth has expanded this analysis, identifying two general types of innovation.[18] The incremental

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[15] M. van Creveld, <u>Technology and War: From 2000 B.C. to the Present</u> (Brassey's (U.K.), 1991), p. 223.

[16] S. Sandler, "Technology and the Military," U. S. Naval Institute <u>Proceedings</u>, vol. 98, no. 3 (March 1972), p. 55.

[17] V. Davis, <u>The Admirals Lobby</u> (Chapel Hill: The University of North Carolina Press, 1967), p. 73.

[18] R. J. Kurth, "The Politics of Technical Innovation in the United States Navy," Unpublished doctoral dissertation, Harvard University, Cambridge, MA: 1970, p. 2.

innovation serves to enhance the position and prestige of established groups within the Navy. These innovations can be promoted without endangering the interests of the established officer communities. Examples of incremental innovations include the installation of radio[19] and radar equipment[20] in fleet units and the acquisition of nuclear weapons for delivery by carrier-launched aircraft.[21] Divergent innovations, on the other hand, reduce the influence of an officer community or change the balance of power among communities within the Navy.

The most obvious example of a divergent innovation in the U.S. Navy is the advent and growth of carrier aviation that eventually displaced the battleship as the core of the United States battle fleet. Kurth cites the shift to nuclear powered submarines as another example of a divergent innovation.[22] Hyman G. Rickover largely prevented diesel boat officers from cross-training and shifting to nuclear-powered boats. Consequently, conventional submarine officers were displaced by nuclear-trained officers. Divergent innovations threaten the established power structure and are likely to be blocked unless external influence is applied to the organization. For the U.S. Navy, this means political pressure (e.g., Congressional directives or Presidential intervention).

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[19] S. J. Douglas, "The Navy Adopts the Radio, 1899-1919," M. R. Smith, ed., Military Enterprise and Technological Change: Perspectives on the American Experience (Cambridge: MIT Press, 1985), pp. 117-173.

[20] D. K. Allison, New Eye for the Navy: The Origins of Radar at the Naval Research Laboratory, (Washington D.C.: Naval Research Laboratory, 1981).

[21] Davis, Admirals Lobby, p. 190.

[22] Kurth, "Politics," p. 98.

The distinction between incremental and divergent innovations should not suggest that it is easy to adopt incremental innovations. The continuous-aim gunfire system developed by the Royal Navy and championed by Lieutenant W. S. Sims in the U.S. Navy was an incremental innovation that threatened no group within the Navy. If adopted, it would only make gunfire systems more accurate. Yet, the continuous-aim system became the subject of an extended controversy within the U.S. Navy. The conflict resulted from legitimate differences of professional opinion among members of the officer corps, combined with some considerable distaste for Sims' confrontational approach.[23] Had the proposal threatened the influence or careers of other officers the conflict could have been even more severe.

The Royal Navy's reaction to Arthur Pollen's fire control system for battleships is another classic case of an incremental innovation that was staunchly resisted by a military organization. Between 1900 and 1912, Pollen conceived and developed a method of fire control that promised to enhance the effective firepower of ships at sea. However, adoption of Pollen's system by the Royal Navy was largely blocked by officers within the Bureau of Ordnance, until after the Royal Navy's mediocre performance at the Battle of Jutland (31 May 1916), following equally poor demonstrations of naval gunnery at the Battles of the Falklands (December 1914) and Dogger Banks (January 1915).

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[23] E. E. Morison, Admiral Sims and the Modern American Navy (Boston: Houghton Mifflin Company, 1942), p. 122.

Subsequently, all British capital ships were equipped with fire control systems that were derived from Pollen's work.[24]

Interservice political rivalries can also block innovation. Neither the Royal Navy nor the German Navy had fully developed and integrated airpower into their fleets prior to the Second World War. William Murray attributes these failures to pre-war political interference from the Royal Air Force and Luftwaffe, respectively. The German Navy actually built and launched, but never sailed an aircraft carrier, the Graf Zeppelin.[25] Interservice rivalries, especially with the U. S. Air Force, have undoubtedly influenced Navy innovation.[26]

There is an interesting counterpoint to the problem of military innovation. Martin van Creveld has observed that, although military organizations might be conservative, they also possess tremendous economic and technological resources for technological innovation.[27] The military has the capability to draw on a nation's entire resources in times of crisis. Consequently, the military is capable of innovating technology where other sectors of a nation are not.

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[24] A. Pollen, The Great Gunnery Scandal: The Mystery of Jutland (London: Collins, 1980); J. T. Sumida, In Defense of Naval Supremacy: Finance, Technology and British Naval Policy, 1889-1914 (Boston: Unwin Hyman, 1989), pp. 297-316; J. T. Sumida, ed., The Pollen Papers: The Privately Circulated Printed Works of Arthur Hungerford Pollen, 1901-1916 (London: Naval Records Society, 1984).

[25] W. Murray, "Neither Navy Was Ready," U. S. Naval Institute Proceedings, vol. 107, no. 4 (April 1981), p. 38.

[26] V. Davis, Postwar Defense Policy and the U. S. Navy, 1943-1946 (Chapel Hill: University of North Carolina Press, 1967), pp. 138-206.

[27] van Creveld, Technology, p. 221.

The lack of defense systems to counter SSMs and the absence of SSMs in the U. S. Navy's arsenal in 1967 has been cited as an example of a military organization's failure to innovate. A former Chief of Naval Operations, Admiral Elmo Zumwalt, blamed the failure on naval aviators who feared a threat to their "union."[28] Historians have echoed Zumwalt's views.[29] A recent naval scholar, William M. McBride, takes a similar position: "Through suppression and limitation of new technologies, the aviation hierarchy has been able to maintain the preeminence of its strategic doctrine and its social power within the navy."[30] With specific reference to cruise missiles, McBride argues that:

> Like the airplane, the cruise missile was developed outside the navy. It has been adopted by the navy, but remains a technological alternative to manned aircraft, the chosen artifact of the navy's social elite. Aviators reject the idea that they are no better than manned missiles and continue to define force projection in terms of traditional air strikes launched from aircraft carriers. This is the one military option that has been consistently presented by the navy to the White House over the last decade.[31]

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[28] E. R. Zumwalt, Jr., "High-Low," U. S. Naval Institute Proceedings, vol. 102, no. 4 (April 1976), p. 55; E. R. Zumwalt, Jr., On Watch (New York: Quadrangle-New York Times Book Company, 1976), p. 81.

[29] R. J. Art and S. E. Ockenden, "The Domestic Politics of Cruise Missile Development, 1970-1980," R. K. Betts, ed., Cruise Missiles: Technology, Strategy, Politics (Washington, D.C: Brookings Institution, 1981), pp. 349-390; Fahrney, "History," pp. 1094-1097; Robert W. Love, Jr., History of the U.S. Navy, 1942-1991, (Harrisburg: Stackpole Books, 1992), p. 644. D. K. Stumpf, "Blasts from the Past," U. S. Naval Institute Proceedings, vol. 119, no. 4 (April 1993), p. 64; Werrell, Evolution, p. 150.

[30] W. M. McBride, "The Rise and Fall of a Strategic Technology: The American Battleship from Santiago Bay to Pearl Harbor, 1898-1941," Unpublished doctoral dissertation, The Johns Hopkins University, Baltimore, MD:1989, p. xxi.

[31] McBride, "Strategic Technology," pp. 358-9.

## CHAPTER III

## TECHNOLOGICAL INNOVATION IN THE MILITARY

"History is in fact full of examples of armies and navies that were defeated and went on being defeated because they did not innovate."[1]

Episodes of technological innovation dominate the history of warfare and have changed the character and practice of war. Technological innovation in warfare predates western civilization; the early phases of human culture are identified by their degree of technological advancement in the construction of implements employed for, among other things, combat (e.g., the Bronze Age). The chariot and composite bow, for example, are two innovations that changed the nature of warfare, long before the emergence of the classical Greek society. John Keegan cites evidence that the Sumerians possessed the composite bow by the reign of Naram-Sin (2260-23 BC).[2] The chariot followed shortly thereafter, leading to the development of fortified strongholds in one of the earliest recorded arms races.[3]

Inventors, scientists, and the military have been partners in technological innovation since the dawn of western civilization. Joel Mokyr, a scholar who has chronicled the relationships between technology and wealth, credits Greek and Roman

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[1] S. P. Rosen, Winning the Next War: Innovation an the Modern Military (Ithaca: Cornell University Press, 1991), p. 9.

[2] J. Keegan, A History of Warfare (New York: Alfred A. Knopf, 1993), p. 135.

[3] Keegan, History, p. 139.

scientists with significant contributions to military technology through the construction of war machines.[4] Throughout its history, the U.S. Navy has benefited from civilian technological expertise. The contributions of John Ericsson to warship design (USS Monitor) during the Civil War is the stuff of naval legend. Prominent American scientists and inventors provided guidance and technical support to the U.S. Navy during the World War I era, through service on the Naval Consulting Board, established by Secretary of the Navy Josephus Daniels and organized by the renowned inventor Thomas A. Edison in October 1915.[5]

Throughout recorded history, there are countless examples of technological innovations which were coopted for military applications. Some scholars have also made a complimentary claim; military innovation spurs the application of civilian technology.[6] Regardless of the relative contributions of the civilian and military sectors to technological advancement, it is self-evident that technology has changed the face of warfare through the centuries. This chapter has two purposes: first, to examine the concept of technological innovation; and second, to propose one means of defining innovation that permits a detailed evaluation of progress in technological innovation.

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[4] J. Mokyr, The Lever of Riches: Technological Creativity and Economic Progress (Oxford: Oxford University Press, 1990), p. 21.

[5] Robert W. Love, Jr., History of the U.S. Navy, 1775-1941 (Harrisburg: Stackpole Books, 1992), p. 490.

[6] Mokyr, Lever of Riches, pp. 183-185.

## Concepts of Innovation

On first consideration, the notion of innovation appears to be a simple concept, but the literature on innovation includes a surprising number of distinctly different and complex definitions. The various concepts of innovation actually incorporate a wide variety of social and technological phenomena. Authors who have studied the issue generally focus on a particular definition or interpretation of innovation that they have adopted. For example, S. P. Rosen's important study of military innovation employs the following definition:

> A 'major innovation,' as I use the term here, is a change that forces one of the primary combat arms of a service to change its concepts of operation and its relation to other combat arms, and to abandon or downgrade traditional missions. Such innovations involve a new way of war . . . [7]

This definition seems unnecessarily restrictive. It excludes innovations that radically alter military capabilities without changing the basic roles of a service's combat arms. For example, Rosen does not consider the U.S. Navy's acquisition of nuclear weapons to be an innovation. His position on naval nuclear weapons ignores the change in naval missions mediated by the new weapons and the importance of nuclear weapons in

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[7] S. P. Rosen, "New Ways of War: Understanding Military Innovation," International Security, vol. 13, no. 1 (Summer, 1988), p. 134. For a similar view, see M. Evangelista, Innovation and the Arms Race: How the United States and the Soviet Union Develop New Military Technologies (Ithaca: Cornell University Press, 1988), p. 12.

maintaining a role for naval aviation in the nation's post-war defense.[8] Rosen's definition might better apply to a subset of innovations that includes only major political and technological change, the technological revolution, wherein the basic roles of the components of a military service are changed by the introduction of a technological innovation.

As noted in the previous chapter, another student of military innovation, Ronald J. Kurth recognized two general categories of innovation: incremental and divergent.[9] Incremental innovations improve the capabilities of existing systems without hazarding the political influence of any established group. "Innovative departure is a radical departure from the technology supporting existing weapons systems. Innovative departure destabilizes naval organization . . ."[10] Rosen's definition incorporates only the divergent innovation, relegating Kurth's incremental innovation to an undefined semantic limbo. Kurth's approach has merit because it properly includes the broad spectrum of technological innovation, regardless of its political impact.[11]

[8] V. Davis, Postwar Defense Policy and the U.S. Navy, 1943-1946 (Chapel Hill: University of North Carolina Press, 1962), pp. 190-199.

[9] R. J. Kurth, "The Politics of Technological Innovation in the United States Navy," Unpublished doctoral dissertation, Harvard University, Cambridge, MA: 1970, p. 2.

[10] Kurth, "Politics," p. 3.

[11] Berend Bruins has constructed a classification, using Kurth's method, of the different bombardment missile programs active between 1940 and 1958. However, he overlooks several earlier or concurrent programs. Consequently, some of the projects he identifies as "Divergent" are not: B. D. Bruins, "U. S. Naval Bombardment Missiles, 1940-1958: A Study of the Weapons Innovation Process," Unpublished doctoral dissertation, Columbia University, New York, New York: 1981, p. 280.

Most of the scholars who have addressed the problem of technological innovation treat their subject as an article, in terms of a new device, weapon, tool, or other item that alters the capabilities of the military. This definition allows an overly simplified treatment of the subject: either the technology is obtained or it is not. An innovation is successful or it is not. This approach has some advantages, but such simplification risks losing opportunities for understanding the nature of change.

The shortcomings of an overly simplified analytical approach are reflected in the literature on naval innovation. Critics of military technological innovation generally analyze change with an odd, Boolean logic. Either the innovation succeeds (is acquired and deployed) or it does not. For example, the Navy's cancellation of the Regulus II cruise missile in 1959, discussed in the foregoing chapter, was cited as a failure to innovate regardless of the time and resources invested in the project or the reasons for the cancellation.[12] Closer examination of the process of innovation can facilitate a better understanding of the causes of success and failure in naval innovation, placing it in the context of the resources, perceived needs, technical obstacles, and information available to the naval leaders at the time they made key decisions.

Broadly defined, innovation is a process rather than an article; it is the process of creating, promoting, developing, deploying, and integrating change, including new

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[12] E. R. Zumwalt, Jr., "High-Low," U. S. Naval Institute Proceedings, vol. 102, no. 4 (April 1976), p. 55; E. R. Zumwalt, Jr., On Watch (New York: Quadrangle-New York Times Book Company, 1976), pp. 80-81.

technology, into military organizations.[13] The definition includes virtually any change in the hardware (or software!) that military personnel utilize. It focusses not on the technologies themselves, but on the processes that led to their adoption and use by the military.

There are many forms of innovation.[14] The most obvious form of innovation involves the incorporation of new technology into military weapons, command and control, and support systems, but new tactics or organization can also constitute military innovations. During the Napoleonic Era, the French army was organized into sub-units such as battalions, demi-brigades, and divisions. This organization provided a flexibility and command structure that was previously unknown in warfare. Another classic case of an organizational innovation is the formation of the Prussian General Staff under Moltke in the late 19th century. In the modern United States armed forces, the formation of Air Force composite wings constituted organizational innovations that are unrelated to any technological advance.[15]

New tactics, operational art, or strategy can have a profound impact on the course of a war. During the First World War, Great Britain suffered heavy losses of shipping to German U-boats operating in the Atlantic. The shift from the independent sailing of merchants to convoys guarded by British warships greatly reduced merchant sinkings and

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[13] B. D. Bruins recognized this distinction: Berend D. Bruins, "Naval Bombardment Missiles," p. 29.

[14] Rosen, "New Ways," pp. 134-137.

[15] The composite wing is an innovation for the Air Force, but the Marine Corps have employed composite wings for years.

increased the losses to the German submarine fleet.[16] Failure to appreciate these hard-earned insights can also have profound effects, as the U.S. Navy discovered again, early in World War II when German submarines devastated shipping off the east coast of the United States.[17]

Innovation in one area can stimulate or even require change in other areas. The advent of naval aviation, for example, was a technological innovation that engendered change in tactical and operational art as well as an organizational change within the U.S. Navy. Acquiring a new technology does not complete the innovation process. Instead, the process is completed when the organization has fully adopted and adapted to the new technology.

### Components of Technological Innovation

New technologies are usually not acquired fully formed and ready for combat. There is a series of developmental stages leading from the initial conceptualization to the final deployment of any technological innovation through which each innovation must pass. These stages include conceptualization, research and development, operational evaluation, tactical-operational-strategic integration, and deployment. These stages do not necessarily flow in sequence. New technology can be integrated into current military tactics, operational art, or strategy at any stage of the process, but each of these phases

[16] A. J. Marder, From the Dreadnought to Scapa Flow: The Royal Navy in the Fisher Era 1904-1919 (Oxford: Oxford University Press, 1969), vol. 4, pp. 115-166.

[17] E. A. Cohen and J. Gooch, Military Misfortunes: The Anatomy of Failure in War (New York: The Free Press, 1990), pp. 59-94.

must be accomplished if the organization is to fully realized the advantage of any given innovation.

The progress of a new technology through the various stages of the innovative process is strongly influenced by the political support for the technology within the military. Political support accrues through a predictable pattern of activity by advocates. Zealots who proselytize their warfare community on the virtues of the new technology often initiate the growth of support. These zealots frequently solicit the support of senior officers or powerful individuals outside the military with whom they form alliances. Finally, if organization is to commit its resources to the newly developing technology, it is necessary to have committed individuals positioned in the organization where the critical decisions are made. Political considerations are treated separately in this paper but, in actuality, politics are an integral part of the innovative process.

Conceptualization. The first phase of the innovation process is to conceptualize the new technology. Often the innovation involves no single new technology, but several technological advances applied in concert.[18] K. Lautenschlager's study of the Dreadnought demonstrated that this naval innovation extended far beyond the obvious combination of a large, fast, armored ship with big guns. The Dreadnought required new optical systems to facilitate fire control and internal electrical systems to coordinate gunfire. Thus, the integration of new systems might be as significant as the introduction

[18] V. Davis, "The Politics of Innovation: Patterns in Navy Cases," University of Denver Social Science Foundation and Graduate School of International Studies Monograph Series in World Affairs, vol. 4, no. 3 (1966-67), p. 52; F. C. Mahncke, "From Technology to Tactics: Finding the Missing Link," Naval War College Review, vol. 42, no. 2 (Spring 1989), p. 101.

of a new technology.[19] The development of modern cruise missiles involves a similar integration of new technologies; the combination of newly developed small and efficient jet engines combined with microelectronic guidance systems made a new generation of cruise missiles possible.[20] Typically, conceptualization requires not only the idea of a new technology, but also insight necessary to envision the role of that technology in future conflicts: a vision of future war.

Technological innovations in the U.S. Navy tend to derive from different sources. The most obvious source is a U.S. citizen, either within the military or not, who brings their idea to the attention of the Navy. A second source of new concepts is the nation's rival states. In this instance, intelligence gathered on other nations constitutes the means of acquiring new concepts.[21] Such information can generate technological initiatives either to replicate a rival's technology or to prepare countermeasures to counter the rival's innovative activity. A nation's allies might also transfer information or new technology.

In any case, the first decision to confront the military organization is whether or not to research and develop the new technology. In considering a decision to pursue research and development of a new technology, the anticipated development time is

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[19] K. Lautenschlager, "The Dreadnought Revolution Reconsidered," D. M. Masterson, general ed., Naval History: The Sixth Symposium of the U.S. Naval Academy (Wilmington: Scholarly Resources, 1987). pp. 121-142.

[20] K. Tsipis, "Cruise Missiles," Scientific American, vol. 236, no. 2 (February 1977), p. 21.

[21] M.I. Handel, "Technological Surprise in War," Intelligence and National Security, vol. 1, no. 1 (January 1987), pp. 30-38.

often a critical variable. Military leaders frequently expect new technology to be available quickly and become frustrated when extended periods of development time are necessary. Scientists and engineers, on the other hand, often cannot estimate the time necessary to solve the problems that confront them. Such decisions are not easy because they involve a cost-benefit analysis of technologies with inherently uncertain benefits. These cost-benefit analyses tend to be more difficult when the benefits accrue far in the future, because of the uncertainties about the future of warfare. In essence, managers must balance the estimated costs and time necessary for development against the uncertain value of technology in future conflict.[22]

Research and Development. The next phase of the innovative process is research and development (R & D). This is the time when it becomes necessary to devote ever precious resources to a new technology. In some cases, the eventual success of the research and development effort might be uncertain. Consequently, there can be a significant element of risk in the decision to embark on a R & D project. The risk can often be minimized by pursuing several technological solutions in the project's early

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[22] For discussions of this problem, see M. A. Libby III, "Technology, Hardware, and Occam's Razor," U. S. Naval Institute Proceedings, vol. 114, no. 10 (October 1988), p. 50; Rosen, Winning, pp. 221-250.

phases.[23] In other cases, particularly when a rival nation's activities suggests the concept for new technology, R & D might be minimal.[24]

Progress in R & D also is usually resource-dependent, with progress accelerating or declining as funding waxes and wanes. Thus, progress is difficult to predict when funding is subject to unanticipated change. Also, unexpected technical difficulties can lead to unexpected delay and increased expense.

Operational Evaluation. Operational evaluation involves testing new technologies under the actual or simulated conditions where the technology might be actually employed. In some cases, operational evaluation might involve limited deployment of a new weapon in a minor conflict to test its effectiveness. For example, several weapons were employed extensively in Operation Desert Storm as an intentional, real-war operational evaluation. Another option is to provide the technology to a trusted ally nation that can evaluate the technology in an actual conflict. Lacking a actual combat situation, technologies can be tested under simulated conditions, such as a fleet exercise.

The transition from research and development to the next phase of the innovative process, operational evaluation is often blurred. The extensive testing necessary in the R & D phase often extends into the operational evaluation, so that there is no distinct

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[23] T. C. Hone and M. D. Mandeles, "Interwar Innovation in Three Navies: U.S. Navy, Royal Navy, Imperial Japanese Navy. Naval War College Review, vol. 40, no. 2 (Spring, 1987), p. 77.

[24] An excellent example of a technology where minimal R & D was required was the replication of the German V-1 cruise missile. It only required technicians three weeks to reverse-engineer the first JB-2 missile from German components: K. P. Werrell, Evolution of the Cruise Missile (Maxwell Air Force Base: Air University Press, 1985), p. 63.

boundary between the two phases. Nevertheless, the decision to advance to the operational evaluation of a new technology represents another threshold that requires the active involvement, and assent, of Naval officials.

Deployment. The deployment of a new technology represents the fruition of the innovative process. Decisions to deploy a new technology are still risky; operational evaluations can prove misleading and an inappropriate decision can be expensive.[25] Efforts to accelerate deployment by initiating deployment before the completion of operational evaluation require Navy officials to commit to a decision before the necessary information is available.

Innovation and DSARC Milestones. It should not pass unnoticed that the four phases of innovation described herein generally correspond to the four phases of the Defense Acquisition Process.[26] Concept formulation corresponds to conceptualization; demonstration and validation together with engineering development roughly equates to R & D. TECHEVAL and OPEVAL are the counterpart of the operational evaluation

[25] One such decision in the recent past is the infamous DASH, or Drone Anti-Submarine Helicopter. While successful in operational evaluation (probably because sufficient technical expertise was available on mother ships) the loss rate of expensive DASH systems proved intolerable and the program was cancelled: Armed Forces Journal, "Dash Continues to Crash," 27 December 1969, vol. 107, p. 13; Armed Forces Journal, "GAO Hits Navy DASH Concurrency Problems," 1 February 1971, vol. 108, p. 10.

[26] The Joint Staff Officer's Guide 1993 (Washington D.C: U. S. Government Printing Office, 1993), pp. 5-19-23.

employed here, and production corresponds to deployment.[27] However, the Defense Acquisition process does not explicitly address the issues of integration discussed below.

## Tactical Integration

New technologies must be integrated into a warfighting community's tactics, operational art, and even strategy if they are to be exploited fully.[28] To a limited extent, the current concept of war will guide the development of new technologies. The more profound advances, however, often stretch or exceed the limits of existing concepts about the nature of war. Radical changes in technology redefine the conduct of war. This transition is not simple, because it requires changing the naval community's concept of war. It also requires time. Altering this concept requires altering the way that the military trains for, thinks about, and prepares for war. For example, the advent of effective anti-ship cruise missiles has necessitated change in both defensive and offensive naval tactics.[29] Conflict during a period of integration might be especially hazardous, when the transition from the old to the new is incomplete because of the resulting

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[27] See D. Lambell, "The Weapons We Buy," U. S. Naval Institute Proceedings, vol. 107, no. 8 (August 1981), p. 57.

[28] B. R. Inman, Technology and Strategy, U. S. Naval Institute Proceedings, vol. 110, no. 12 supplement (December 1984), p. 44; B. R. Rosen, The Sources of Military Doctrine: France, Britain, and Germany Between the World Wars (Ithaca: Cornell University Press, 1984), pp. 29-33.

[29] W. J. Ruhe, Antiship Missiles Launch New Tactics," U. S. Naval Institute Proceedings, vol. 108, no. 12 (December 1982), p. 60

confusion and poor coordination.[30] Organizational inertia sometimes extends the time necessary to complete the necessary integration.[31] Frank Mahncke has suggested the transition might be eased by careful selection of the individuals tasked to integrate new technologies into a warfare community:

> The key to a successful transition from technology to tactics lies not in the bureaucratic structure (though that might be improved) but in finding the right people. Individuals are needed who have the flexibility of mind and intellect to understand and work with both technology and tactics.[32]

### Political Inputs Into the Innovation Process

The innovation process is not driven by pure analysis and abstract evaluation. People and the relationships between people inevitably influence the activity of organizations. Any evaluation of efforts to innovate that ignores the human component would necessarily be incomplete.

Champions and Zealots. Typically, new technologies are championed by one or more officers who commit their energy, prestige, and very careers to promoting the new technology. Depending upon one's point of view, one can be label such officers as Champions or Zealots. Examples of such zealots are plentiful in the history of the modern Navy. Lieutenant William Sims' vigorous promotion of the continuous aim

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[30] B. R. Posen, The Sources of Military Doctrine: France, Britain, and Germany Between the World Wars (Ithaca: Cornell University Press, pp. 29-33.

[31] A. T. Mahan, The Influence of Sea Power Upon History, 1660-1783 (reprint, New York: Hill and Wang, 1957), p. 8.

[32] F. C. Mahncke, "From Technology to Tactics: Finding the Missing Link," Naval War College Review, vol. 42, no. 2 (Spring, 1989), p. 103.

system of naval gunfire was mentioned earlier as one example. Others include Rear Admiral William Moffett and Captain John H. Towers, early proponents of naval aviation, as well as Captain Hyman G. Rickover, the legendary champion of nuclear power. Without the tireless efforts of such officers, it is doubtful that innovations would be adopted, at least so quickly. But the zealots could not succeed without some measure of support from powerful individuals within the Navy.

In his study of naval champions, Davis notes that the typical zealot is an experienced junior or field grade officer who did not conceive or invent the new technology, but who become a passionate, ardent supporter of the technology.[33] Sims, for example, only recognized the value of an innovation developed in the Royal Navy. Neither Moffett nor Towers conceived of or invented naval aviation, and Rickover did not invent the nuclear reactor, but each of these officers recognized potential value in a new technology and devoted a substantial portion of their career to promoting it.

Vertical Alliances. The U.S. Navy, as an organization, takes a formal position on technological innovation when the responsible officials in the office of the Chief of Naval Operations stake out the Navy's view on an issue. But the Navy is composed of people, and there can be a considerable range of opinion hidden beneath the official Navy position. Equally important, a range of views generally develops among the senior naval officers before the Navy staff adopts an official position. This was especially important during the era when considerable power rested with semi-autonomous bureau chiefs. In many cases, zealots seeking to promote new technologies have been able to attract the

[33] Davis, "Politics," pp. 51-55.

support of flag officers within the Navy, and this support has greatly facilitated the innovative process. Vincent Davis has labelled this association a "vertical alliance."[34] Where zealots were unable to attract sufficient support from flag officers, they will sometimes reach outside the military organization and attempt to solicit political support for their endeavor.[35] Lieutenant Sims wrote directly to President Roosevelt seeking the President's support for his proposals to improve naval gunnery.[36] Hyman Rickover's congressional alliances are another example of extra-organizational vertical alliances.

Alliances are dynamic; they change through time as support for a technology waxes and wanes. For example, prior to the entry of the United States into World War II, Rear Admiral John H. Towers supported the development of cruise missiles ("assault drones") and raised the priority for cruise missile research and development.[37] Three years later, the same officer opposed the operational evaluation of cruise missiles and actively obstructed the innovative process.[38] These dynamics make historical analysis of alliances more difficult. Nevertheless, the existence of such support, either internally or from outside the organization, is sufficiently important that efforts be made to identify the significant vertical alliances.

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[34] Davis, "Politics," pp. 55-56.

[35] Davis, "Politics," p. 56.

[36] E. Morison, Admiral Sims and the Modern American Navy (Boston: Houghton Mifflin Company, 1942), pp. 102-104.

[37] W. F. Trimble, Wings for the Navy: A History of the Naval Aircraft Factory, 1917-1956 (Annapolis: Naval Institute Press, 1990), p. 201.

[38] D. S. Fahrney, "The Birth of Guided Missiles," U. S. Naval Institute Proceedings, vol. 106, no. 12 (December 1980), p. 58.

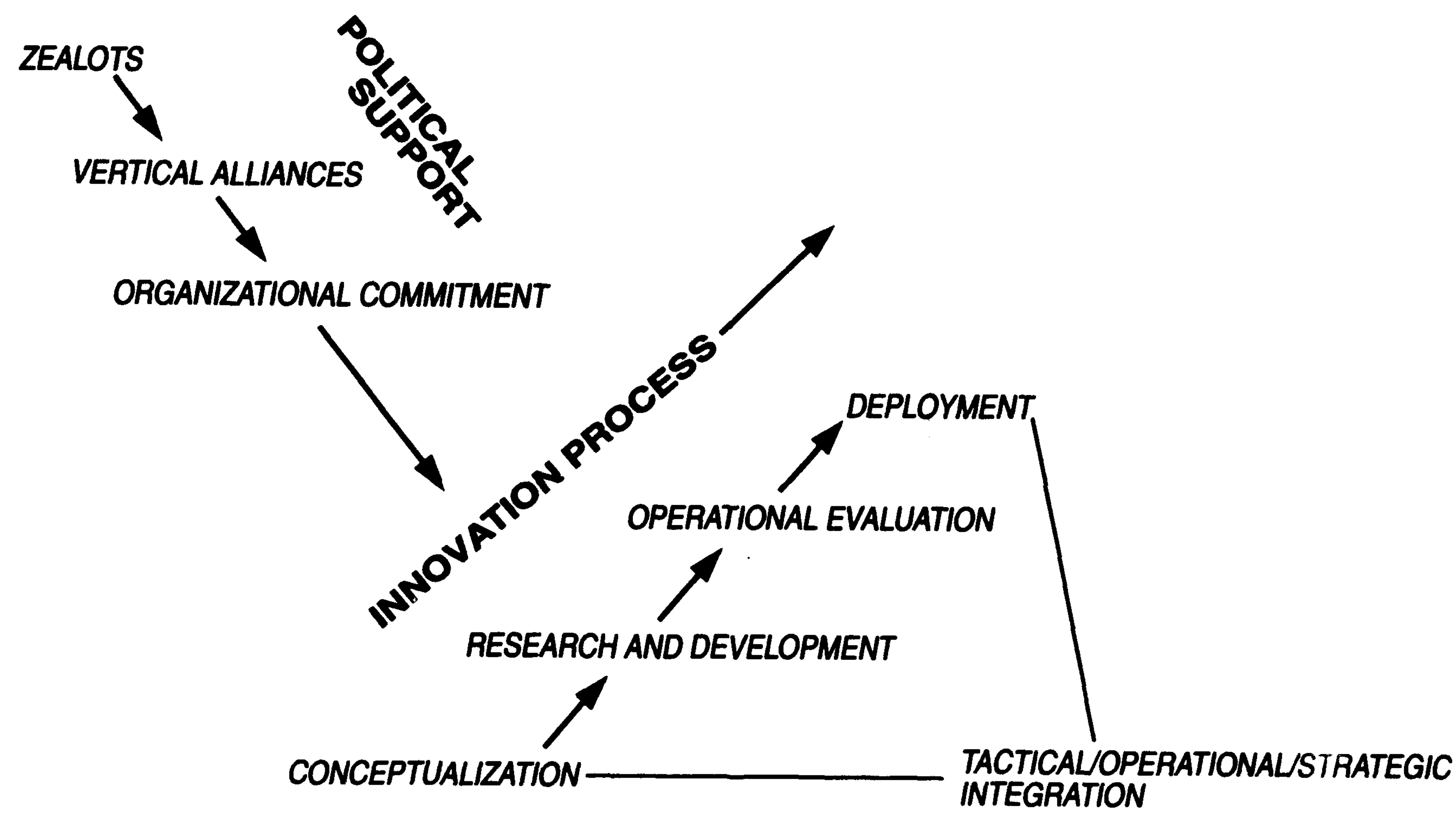
Organizational Commitment. New technologies will not survive the innovation process unless they gain the organizational commitment of the U.S. Navy. Regardless of the agitation of zealots or the support they garner through vertical alliances, it is the decisions of individuals within the organization, individuals with positional power, who are assigned the responsibility for making decisions about research and development, operational evaluation, and deployment who determine the future of a new technology. Obtaining this organizational commitment is the objective of the zealot.

## Overview of the Innovation Process

Figure 1 summarizes the flow of the innovative process as outlined in the foregoing chapter. The figure is not intended as a detailed portrait of the innovative process. Instead, it is a framework that can be employed to examine the Navy's efforts in developing cruise missiles. Political considerations are a key element throughout the primary sequence of the innovative process, from conceptualization to deployment. The tactical, operational, and strategic integration of the technology alongside existing equipment is not directly linked to any single stage of the innovative process, but it is something that must be completed if the new technology is to be fully utilized.

Figure 1 obviously presents a simplified view of the innovation process. The innovative process itself is more complex than the simple four steps illustrated. Political considerations should include the views of officers that are not directly involved in the innovation process. Those views will surely have an influence, however subtle, on the eventual outcome of the process. The opinions of individuals outside the military, especially civilians who can wield political power, will also be important. Integrating the new technology into the service, including the requisite changes in doctrine and training, is a complex task. Acknowledging that these complexities exist, it is now possible to proceed to an examination of the history of the Navy's efforts to develop cruise missiles.

## FIGURE 1
## COMPONENTS OF INNOVATION




94-ADVR45

## CHAPTER IV

## U. S. NAVY CRUISE MISSILE PROGRAMS, 1916-1985

"It is easy to imagine a fleet of these weapons, loaded with deadly gas or explosives, launched against an objective without endangering one human life of the side so employing them."[1]

Through much of the 20th Century, the United States Navy endeavored to develop cruise missiles that could be employed effectively against other ships and in shore bombardment. This effort culminated in the successful deployment of the Harpoon and Tomahawk cruise missiles. However, the Navy's efforts did not occur in a vacuum; the U. S. Army Air force and later the U.S. Air Force, along with the armed services of other nations pursued significant and relevant cruise missile programs at different times during this century.[2] An outline of the U. S. Navy's progress permits an evaluation of the Navy's capacity for innovation in the general area of cruise missile technology, without submerging the general purpose in historical detail.[3]

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[1] Lawrence Sperry's concept of cruise missile strike warfare, written sometime prior to his death in 1923 and published posthumously in 1926: L. Sperry, "The Aerial Torpedo," U. S. Air Services, January 1926, p. 16.

[2] A complete review of the history of cruise missiles is beyond the scope of this paper. For a relatively complete and balanced history of cruise missile development, the reader might wish to refer to K. P. Werrell, The Evolution of the Cruise Missile, (Maxwell Air Force Base: Air University Press, 1985).

[3] For example, there are numerous published works, plus more than 600 unpublished manuscript pages, chronicling the Regulus cruise missile alone. Such detail is unnecessary for the purpose at hand.

## Lawrence Sperry's Aerial Torpedo, 1916-1922

Conceptualization. The origins of the cruise missile concept are difficult to locate. Prior to the outbreak of World War I, aviators in several nations experimented with remote-controlled pilotless aircraft known as "flying bombs" or "aerial torpedoes." While these efforts failed to produce a deployable weapon, the concept of the cruise missile can be traced to this era. The inventor, Elmer Sperry, and his equally talented son, Lawrence, proposed an aerial torpedo project to Navy officials in 1916, envisioning it as both a sea control weapon that could sweep enemy ships from the oceans and as a shore b ardment missile.[4] The flying bomb was the conceptual sequel to Lawrence Sperry's

[4] The details of Elmer Sperry's involvement in the aerial torpedo project are unclear. Some historians (Pearson, Fahrney, Hughes) attribute much of the technology and concept for the aerial torpedo to the elder Sperry, assigning Lawrence a secondary role as test pilot and assistant. In contrast, others (Davenport, General "Billy" Mitchell) grant Lawrence Sperry the credit for inventing the gyroscope-based autopilot on which the concept of the aerial torpedo was based and for independently pursuing the development of the technology. Charles L. Keller, apparently drawing on Fahrney's unpublished work, presents a third view, stating that another noted inventor and member of the Naval Consulting Board, Peter Cooper Hewitt, first conceived of the aerial torpedo and brought his ideas to the attention of Elmer Sperry. T. S. Wilkinson, in his correspondence with Rear Admiral Earle dated 13 September 1916, refers to Mr. Hewitt's offer to demonstrate a drone aircraft in August, 1916. His letter suggests that Hewitt was representing the Sperry-Hewitt project to the Navy. Daniel M. Parker offers still another view, giving Glenn Curtiss credit and stating that the Navy contracted with Curtiss, not Sperry, to deliver the aerial torpedo. In an article published posthumously, Lawrence Sperry suggests the concept of the aerial torpedo belonged to French aeronautical engineers, while the first practical design was his own. In an accompanying note, Colonel William (Billy) Mitchell refers to the late Lawrence Sperry as the "great developer" of the aerial torpedo. D. S. Fahrney cites an attempt by Italian Army officers to launch an aerial torpedo in September 1914. Resolution of this conflict lies outside the scope of this paper, but the authorship of various flight-related U. S. patents suggests the bulk of the creative work on the aerial torpedo belongs to Lawrence Sperry. See W. W. Davenport, Gyro! The Life and Times of Lawrence Sperry (New York: Charles Scribner's Sons, 1978); D. S. Fahrney, "The History of Pilotless Aircraft and Guided Missiles," Unpublished Manuscript, Naval Historical Center, 1958, pp. 87, 103; T. P.

earlier work on automated flight control. Lieutenant T. S. Wilkinson[5] observed a demonstration of the Sperry aerial torpedo on 12 September 1916, and reported that the device lacked the accuracy necessary to attack ships at sea but would be useful in for shore bombardment.[6] Elmer Sperry approached the Army seeking support for the aerial torpedo project in August 1916, but was unable to interest them.[7]

Lawrence Sperry's relationship with the U. S. Navy predated the Sperry company's formal contract. In 1914, while working with Glenn Curtiss on development of an aerial stabilizer (forerunner to the autopilot), Sperry worked closely with the pioneer naval aviator (and future Vice Admiral) Patrick Bellinger. Subsequently, Sperry first joined the U. S. Army Aviation Reserve Corps and, later, the United States Navy Flying Corps on 5 January 1917.[8] He was called to active duty on 1 January 1918.[9] However, a severe

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Hughes, Elmer Sperry: Inventor and Engineer (Baltimore: The Johns Hopkins University Press, 1971), p. 243-274, 333-336; L. S. Howeth, History of Communications-Electronics in the United States Navy (Washington D.C: U. S. Government Printing Office, 1963), p. 343; C. L. Keller, "The First Guided Missile Program: The Aerial Torpedo," American Aviation Historical Journal, Winter 1975, p. 268; W. Mitchell, "Lawrence Sperry and the Aerial Torpedo," U. S. Air Services, January 1926, p. 16; D. M. Parker, "The Empty Cockpit," U. S. Naval Institute Proceedings, vol. 110, no. 8 (August 1984), p. 38; L. Pearson, "Developing the Flying Bomb," Naval Aviation News, May 1968, p. 22; Sperry, "Aerial Torpedo," pp. 18-19.

[5] T. S. Wilkinson subsequently reached the rank of Vice Admiral.

[6] Fahrney, "History," pp. 88-89; L. S. Howeth, History of Communications-Electronics in the United States Navy (Washington D. C: U. S. Government Printing Office, 1963), p. 344.

[7] Fahrney, "History," p. 89.

[8] Davenport, Gyro!, p. 137.

[9] Fahrney, "History," p. 105.

bout with appendicitis and an emergency operation at sea ended his active service a few months later.

It is clear that the younger Sperry was pursuing development of the aerial torpedo well before the Navy undertook to support the project. An article in the New York Tribune, dated 21 October 1915, apparently published without Sperry's prior knowledge or consent, foretold many of the fundamentals of the Sperry project.[10] Four months before the Navy awarded a contract for the aerial torpedo, Sperry applied for and eventually received U.S. Patent number 1,418,605 for his invention.[11] In this patent, Lawrence Sperry clearly anticipated many of the attributes of the modern cruise missile, including the range, internal guidance systems, and possibilities for post-launch guidance. The Navy did not initiate the project but embraced it following the outbreak of war.

Research and Development. The Navy did not seriously consider the Sperry aerial torpedo proposal until the United States entered the war on 6 April 1917. Subsequently, the Naval Consulting Board recommended the project be funded.[12] Following a brief committee review,[13] the Secretary of the Navy, Josephus Daniels, allocated $200,000 for the flying bomb project on 22 May, 1917, allowing the project to enter research and

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[10] Davenport, Gyro!, p. 118.

[11] Davenport, Gyro!, pp. 298-305.

[12] The Naval Consulting Board made their recommendations on 14 April 1917: Fahrney, "History," p. 89. Elmer Sperry and Peter C. Hewitt were members of the Naval Consulting Board at the time. Their presence on the board constituted an interesting conflict of interest that would not be acceptable today.

[13] Committee members for the review included Ensign Lawrence Sperry, Lieutenant John H. Towers, Elmer Sperry and Rear Admiral Earle: Fahrney, "History," p. 91.

development (R & D). The Sperry's subsequently entered into a contract to develop the aerial torpedo.

Initial research and development efforts on the flying torpedo were focussed on three areas: aircraft launching, stability in flight, and autopilot control. Getting the drone aloft turned out to be a major hurdle, and a number of catapult systems were devised for the task. Unfortunately, a completely satisfactory catapult was never constructed. Sperry contracted with his old mentor, Glenn Curtiss, to manufacture an aircraft (the flying bomb) designed expressly for the task. Curtiss delivered six of the new aircraft to Sperry. However, the stability of these biplanes in flight developed into a major problem. Eventually, the stability problem proved to be insurmountable and the project returned to the Curtiss N-9 aircraft as its basic platform. Finally, the Sperry Aerial Stabilizer, the forerunner to the autopilot, proved to be too crude for the relatively precise mission of a cruise missile.

During the initial phases of R & D, human pilots would get the craft airborne and then turn the flying over to the primitive autopilot. In later tests, it became apparent that there were problems with the flying bomb's stability in flight and with the control mechanisms. The first successful catapult launch and flight of an unmanned aircraft was made on 6 March 1918, but difficulties in launching and flight continued. While efforts continued toward solving the launching and flight stability problems continued, the aerial development team sought other means to improve the weapon's accuracy. At the suggestion of the Navy's project supervisor, Western Electric was developing radio control devices for the aerial torpedo.[14] With the close of the war, Lawrence Sperry's involvement with the Navy project ended.

The Navy pursued the project under the supervision of Commander B. B. McCormick, a retired Navy officer recalled to supervise the aerial torpedo project, and two former Sperry employees, Hannibal Ford and Carl Norden. By 1919, the project shifted to modified control equipment designed by Carl Norden and manufactured by Ford Instrument Company. Aircraft manufactured by Witteman-Lewis were substituted for the Curtiss biplanes.[15] Testing moved to Dahlgren, Virginia, in early 1919 and continued through 1921, with both Curtiss aircraft and flying bombs manufactured by the Naval Aircraft Factory, but the continuing lack of progress led to the Navy canceling the project in 1922.[16] The Navy program never produced a missile that could enter operational evaluation but yielded much useful experience in catapult design that would

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[14] The first recorded mention of radio control for the Navy's aerial torpedo is in correspondence to Rear Admiral Earle dated 10 July 1917. Apparently, there were concerns about the presence of German immigrants in Sperry's radio department, so another company was approached for this work. See Fahrney, "History," pp. 92-94.

[15] Fahrney, "History," pp. 115-117.

[16] Davenport, Gyro!, pp. 216-217; Fahrney, "History,", pp. 116-124; Howith, Communications, p. 347; Werrell, Evolution, p. 12.

later prove useful in flight operations at sea.[17] Toward the project's end, the only apparent use for the drone was as an aerial target.

Following the war, the Lawrence Sperry Aircraft Company obtained a contract from the Army to develop aerial torpedoes.[18] In the course of subsequent research and development, Lawrence Sperry successfully developed a remote radio-controlled aerial torpedo. The possibility of a radio-controlled aerial weapon was discussed during the course of the Navy project, in July 1917, and Elmer Sperry applied for a patent on a radio-controlled aerial torpedo in December, 1917.[19] In 1922, Sperry installed radio-control devices in his radio-controlled aerial torpedo and repeatedly succeeded in attacking targets located 30, 60, and 90 miles from the launch site.[20] Sadly, Lawrence Sperry died at a young age in the English Channel, after ditching his airplane on 13

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[17] L. S. Howeth states the Navy's Bureau of Ordnance continued active research on radio-controlled aircraft until 1925, and kept the remote-controlled aircraft project alive until 1936. Their ultimate objective was to produce a radio-controlled target. Carl Norden apparently continued to assist in this endeavor and Commander Stanford C. Hooper, the famed advocate of radio in the Navy, advised on the project. Lt. J. J. Balentine (later Admiral) was the naval supervisor for the project. They succeeded in developing a radio-controlled seaplane. However, interest waned after 1925 and the project's activities were subjected to severe financial restrictions. The project eventually died from a lack of interest: Fahrney, "History," pp. 149-151; Howeth, Communications, pp. 348-351.

[18] Major General George O. Squire witnessed a test of the aerial torpedo on 21 November 1917. He was sufficiently impressed with the weapon to recommend a separate Army program that was subsequently initiated under the direction of Charles F. Kettering. Fahrney, "History," pp. 95-96, 140-174; Hughes, Elmer Sperry, p. 272.

[19] Howeth, Communications, pp. 344-345.

[20] Davenport, Gryo!, pp. 216-217; Fahrney, "History," pp. 143-144.

December 1923. The Army project continued until 1926. Apparently, the projected expense of the weapons exceeded their expected value in combat.[21]

Political Aspects. The Sperry project had the support of the highest levels of the Department of the Navy. The senior officer supervising the project was Commander Benjamin B. McCormick, a retired officer recalled to active duty.[22] McCormick reported to Rear Admiral Ralph A. Earle, Chief of the Bureau of Ordnance, who forwarded favorable reviews of the aerial torpedo to the Chief of Naval Operations, Admiral W. S. Benson. Earle naturally found limits to the utility of Sperry's flying torpedo, mainly the result of the limited accuracy inherent in such primitive guidance systems. Sperry's aerial torpedo would be no threat to the fleet. Nevertheless, Earle envisioned an important role for the flying bomb as a shore bombardment weapon in future conflicts, much like the role the V-1 was to play in the World War II German war effort against Britain. John H. Towers, a future opponent of the cruise missile, apparently supported development of the technology in 1917.[23] Other air power visionaries, including Billy Mitchell, foresaw the capabilities of what would become known as the cruise missile.[24]

The history of Sperry's aerial torpedo differs from later episodes in the history of cruise missile development in one critical respect. The zealots, the young advocates for

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[21] Fahrney, "History," pp. 143-147.

[22] Keller, "First Guided Missile," p. 269.

[23] Fahrney, "History," p. 91.

[24] Mitchell, "Lawrence Sperry," p. 16.

the technology, were entirely outside the Navy. Support for the project was gathered through external political influence, acting through the Naval Consulting Board, rather than within the officer corps.

Rear Admiral Earle had anticipated that the aerial torpedo would be available for combat after only a brief period of research and development.[25] In September, 1917, only a few months into the project, Admiral Earle attempted to accelerate progress by placing Commander McCormick in command of R & D. At the same time, Secretary Daniels began to explore the possibilities for mass production of the aerial torpedo. Unfortunately, the Sperry project never produced a missile that warranted mass production.[26]

## Projects Dog and Fox, 1938-1944

Conceptualization. In 1935, the Chief of Naval Operations, Admiral William H. Standley, attended the London Naval Conference. In the course of his visit to England, Standley was able to observe a demonstration of Britain's Queen Bee, a target drone developed for naval gunnery practice. Standley returned to the United States in 1936, determined to acquire a similar aircraft for the U.S. Navy. His desires coincided with the Commander Battle Force, who had requested an aerial target drone.[27] Rear Admiral

[25] Keller, "First Guided Missile," p. 269.

[26] Keller, "First Guided Missile," pp. 269-270.

[27] Admiral Harris Laning requested radio-controlled target drones on 1 February 1936. CINCFLEET, Admiral J. M. Reeves, concurred in this request: Fahrney, "History," pp. 188-189.

Ernest King, Chief of the Bureau of Aeronautics, received authorization to proceed with developing a target drone on 1 May 1936.[28] Lieutenant Commander Delmar S. Fahrney was assigned as the Officer-in-Charge (OIC) of the radio-controlled target drone project on 20 July 1936.[29]

Upon receiving his assignment, Fahrney quickly developed into a champion of the cruise missile, promoting them for the remainder of his long career (he eventually retired as a Rear Admiral). In his new capacity as project director, Fahrney prepared a memorandum outlining his vision of the Navy's pilotless aircraft program. This memorandum included, among other items, proposals for radio and television-controlled cruise missiles. He also proposed adopting remote-control piloting mechanisms for test flights of new aircraft. Fahrney's memo, dated 6 August 1936, was submitted to the Chief of Naval Operations who approved the portions relating to development of a target drone on 9 September, 1936.[30] As a consequence of the CNO's limited support, the drone program did not involve weapons research until later.

Others had attempted to interest the Navy in cruise missile research. V. K. Zworykin, an early pioneer of television technology, twice approached the Navy with

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[28] Budget constraints led to the failure of a previous effort to develop a target drone, the final chapter in the history of Sperry's aerial torpedo: B. D. Bruins, "U.S. Naval Bombardment Missiles, 1940-1958: A Study of the Weapons Innovation Process," Unpublished Doctoral Dissertation, Columbia University, New York: 1981, p. 67; Also see Howeth, Communications, pp. 479-480; Fahrney, "History," pp. 149-151.

[29] Fahrney, "History," p. 195; W. F. Trimble, Wings for the Navy: A History of the Naval Aircraft Factory, 1917-1956 (Annapolis: Naval Institute Press, 1990), p. 188.

[30] Fahrney, "History," p. 197; Trimble, Wings, pp. 188-190. LT R. F. Jones made a similar recommendation regarding the potential offensive capabilities of radio-controlled drones to the CNO in a letter dated 12 October 1939: Fahrney, "History," p. 313.

proposals to develop television-guided cruise missiles, in 1934 and 1937. In each case, however, he was rebuffed.[31]

Research and Development. Research and development began immediately, and Fahrney's team completed work on a functioning drone aircraft (a modified Curtiss N2C-2) on 15 November 1937. On that day, the first radio-controlled drone aircraft "Nolo" was successfully completed.[32] The first dive bomb test by a drone aircraft was conducted by a N2C-2 drone on the target ship USS Utah (AG-16). The drone was hit and crashed after only 78 rounds were expended by Utah. The Utah's Commanding Officer subsequently concluded that Navy AA defenses were very effective against dive bombers, a conclusion that was born out in subsequent tests. It was, in effect, a lucky hit.[33] In the summer of 1938, a target drone detachment moved to the west coast and was designated Project Dog. Lieutenant Robert F. Jones was appointed Officer-In-Charge of Project Dog while Fahrney remained OIC of drone development. USS Ranger (CV-4) was the first ship to fire on the drone for naval gunnery practice, on 24 August 1938. Ranger gunners failed to shoot down the drone, an indication of naval vulnerability to air attack.[34] Subsequently, they modified other aircraft for drone operation, including

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[31] Howeth, "Communications," p. 485.

[32] Fahrney, "History," p. 211; Fahrney, "Birth," p. 55. Of course, Fahrney's efforts postdated the Navy- and Army-Sperry projects by 15 years. The primary distinction between Fahrney's mission on 15 November 1937 and the earlier efforts was the final phase of the nolo: landing successfully.

[33] Fahrney, "History," pp. 241-244.

[34] Captain J. S. McCain complained after the test that ". . . it was unfortunate that the DRONE was unable to maintain a steady course and speed until after the first burst." In other words, if the enemy flew straight and level then the gunners might have

Vought's O3U-6 Corsair. Fahrney's development team also began to explore other technologies, including the use of television to monitor flights. Captain Marc Mitscher, Acting Chief of the Bureau of Aeronautics, authorized the extended program in October, 1939.[35] In the meantime, Fahrney continued to promote the offensive capabilities of drones. On 26 August 1938, in Fahrney's report of the Ranger exercise to the Chief of Naval Operations, he again recommended investigating the potential offensive uses of drones.[36]

In February, 1940, Admiral Harold R. Stark, the Chief of Naval Operations, directed Fahrney's team to begin development of a radio-controlled bomber. Stark wanted an aircraft that could be employed for low-altitude bombing exercises without hazarding an aircrew. In response, Fahrney proposed development of an assault drone that could deliver either bombs or torpedoes by remote control. Stark approved Fahrney's proposal and designated the program Project Fox.[37] However, little progress was made because of shortages of experienced personnel and equipment. On 17 January 1941, Rear Admiral John Towers, Chief of the Bureau of Aeronautics, raised the priority on Project Fox in attempt to get the program moving. Towers placed high priorities on

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a chance. Quoted from Fahrney, "History," p. 237.

[35] Trimble, Wings, pp. 196-198; Fahrney, "History," pp. 232-234.

[36] Fahrney, "History," pp. 234-5.

[37] Trimble, Wings, pp. 198-199; Fahrney, "History," pp. 309-325. Shortly thereafter, the Chief of the Bureau of Aeronautics, Rear Admiral J. H. Towers, responded to Jones' letter proposing development of offensive drones. In his letter of 11 March 1940, Towers indicated that BUAER was already developing offensive drones: see Fahrney, "History," p. 314.

both development of the cruise missile and a television guidance system for drone aircraft and missiles.[38]

Berend Bruins attributes the delay in initiating cruise missile R & D to obstructive naval aviators, without identifying the individuals involved or their actions.[39] He also states that the Bureau of Aeronautics hampered development of the radio-controlled bomber subsequent to the project's authorization, again without providing substantiation.[40] Bruins credits the onset of the war together with the appearance of another zealot, Captain Oscar Smith, for breaking through the roadblocks that had stopped development of the cruise missile.[41]

In 1941, Lt. R. F. Jones moved to the east coast to assume command of VJ-5, a radio-controlled drone squadron. On 9 July 1941 he submitted a proposal to develop offensive radio-controlled drones to the Chief of Naval Operations. The CNO approved his request on 8 October 1941, and Jones began independent development of radio-controlled cruise missiles. Fahrney believed this work duplicated his efforts at NAF. Subsequent difficulties in obtaining personnel and material led to the project's responsibilities being consolidated in Fahrney's team at NAF Philadelphia.[42]

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[38] Fahrney, "History," p. 325.

[39] Bruins, "Naval Bombardment Missiles," p. 68.

[40] Bruins, "Naval Bombardment Missiles," pp. 69-70.

[41] Also see Fahrney, "History," pp. 229-241.

[42] Fahrney, "History," pp. 331-343.

Project Fox personnel achieved the first successful attack by a drone aircraft on a ship at sea. On 9 April, 1942, USS Aaron Ward (DD-483) was underway in Narragansett Bay, Rhode Island. A TG-2 drone took off from Naval Air Station Quonset Point, under the control of Navy Lieutenant M. B. "Molt" Taylor.[43] The drone successfully located the ship and conducted a torpedo attack using radio and television guidance, with the dummy torpedo passing under the keel of the destroyer. Ten days later, Lieutenant Taylor successfully maneuvered a TV-guided BG-1 drone into a target sled being towed in Chesapeake Bay.[44]

These demonstrations of the combat capabilities of cruise missiles led to the establishment of Project Option within BUAER on 22 May 1942.[45] Captain Oscar Smith was designated Officer-in-Charge and Project Dog was absorbed into Project Option.[46] Smith had been serving as Director of the Plans Division in the Office of the Chief of Naval Operations, and had voiced strong interest and support for the cruise missile project. The objective of the project was to produce a functional cruise missile for combat in the shortest time possible. However, responsibility for research and development of guided missiles remained with Fahrney's Project Fox. Meanwhile, Project

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[43] Ensign Molton B. Taylor was assigned to Project Fox at NAF in 1941, where he initially worked on the target drone project. Fahrney, "History," p. 339-341.

[44] D. S. Fahrney, "The Genesis of the Cruise Missile," Astronautics and Aeronautics, January 1982, p. 37; Fahrney, "History," pp. 328-348; Trimble, Wings, pp. 260-262.

[45] Trimble, Wings, p. 262; Fahrney states that Admiral E. J. King and the Vice CNO, Admiral F. J. Horne, approved Project Option after viewing motion pictures of Project Fox demonstrations: "History," p. 370.

[46] Fahrney, "History," p. 375.

Fox personnel were beginning to evaluate the potential of radar homing mechanisms for cruise missiles.[47]

Project Option's cruise missile had been previously designated the TDN-1, and 100 of the aircraft were ordered by the Bureau of Aeronautics on 23 March, 1942. The TDN-1 was a full-size aircraft powered by two engines mounted one per wing. The missiles were to be produced by the Naval Aircraft Factory, with the stipulation that production of assault drones not interfere with other aircraft programs. On 3 April, 1942, an additional 100 missiles were ordered by the Chief of Naval Operations. The contract for the additional missiles, designated the TDR-1, was awarded to Interstate Aircraft and Engineering Company. Although this missile received a different designation, there was virtually no difference between the two missiles. The order was increased to 1,000 TDR-1s when Project Option was initiated. However, Towers was deeply concerned that expanded production on this scale would interfere with other aircraft programs, and the order was scaled back to 500 missiles.[48] Nevertheless, the Chief of Naval Operations had great plans for the cruise missile, including 18 squadrons to operate the assault drones.[49]

Operational Evaluation. The first TDN-1 flights were successfully completed on 15 November, 1942.[50] The Bureau of Aeronautics Board of Inspection and Survey

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[47] Fahrney, "History," pp. 362-370.

[48] Trimble, Wings, pp. 260-264.

[49] Fahrney, "Genesis," p. 38.

[50] Trimble, Wings, p. 265.

evaluated the TDN-1 in March of the following year and found it to be completely satisfactory. The logical next step was to undertake an operation evaluation of the cruise missile. However, Commodore Smith opposed any operational evaluation that might inform the enemy of new U. S. capabilities before large quantitites of missiles were available for combat. Rear Admiral Towers, on the other hand, insisted upon a combat evaluation before committing to any large scale production. This conflict held up progress on Navy cruise missiles for nearly a year. The missiles were ready for operational evaluation in early 1943, well before the first German V-1 landed on British soil.[51]

Special Tactical Air Group ONE (STAG-1) was established to conduct an operational evaluation of the missiles in the Pacific theater. Commodore Oscar Smith, now in command of STAG-1, had the full support of the Chief of Naval Operations, Admiral E. J. King. But Smith discovered the Commander in Chief of the Pacific Fleet, Admiral Chester Nimitz, was less enthusiastic. Under Nimitz, Rear Admiral John Towers had recently assumed duties as Commander Air, Pacific, and Towers opposed devoting effort to testing the new missiles because the available forces were successful in their engagements with Japanese forces. Towers believed the new weapons were simply not necessary.[52] Also, Nimitz's staff believed that the speed and maneuverability of the

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[51] Fahrney, "History," pp. 377-378, 393.

[52] Towers' attitude might reflect a more general phenomenon: dominant military forces encounter more difficulty innovating than less dominant services, apparently because it is difficult to change what is obviously a winning formula: S. Sandler, Technology and the Military," U. S. Naval Institute Proceedings, vol. 98, no. 3 (March 1972), pp. 59-60.

drones must be improved prior to committing them to combat.[53] In a meeting held in Hawaii on 10 November 1943, Nimitz backed Towers, directing that testing would not proceed without Towers' approval.[54] Smith was subsequently transferred from the guided missiles program and Project Option was reduced in size significantly.[55]

Interest in the use of bombers converted to drones for the European Theater again raised interest in Project Option. Commodore Smith was directed to return to STAG-1 and deploy to the Pacific for Operational Evaluation.[56] Commodore Smith returned to Hawaii in January of 1944 and found Towers still adamantly opposed to any operational employment of the cruise missiles. However, Smith found a political ally in Vice Admiral Raymond Spruance, an officer who had developed a strong personal distaste for Towers.[57] Spruance agreed to employ Smith's missiles in the forthcoming assault on Eniwetok, and Nimitz and King endorsed the plan. Unfortunately, the schedule for the assault on Eniwetok was advanced and STAG-1 could not deploy in time to participate.

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[53] Fahrney, "History," p. 391. The top speed of the TDN-1 and TDR-1 drones was 145 mph (235 km/h).

[54] C. G. Reynolds, Admiral John H. Towers: The Struggle for Naval Air Supremacy (Annapolis: Naval Institute Press), pp. 434-435; Fahrney, "Birth," p. 58. Fahrney presents a different account elsewhere, attributing the slow speeds of the drones (150 knots) to Nimitz's decision not to deploy them: "History," pp. 391-393.

[55] Fahrney, "History," pp. 395-401.

[56] Fahrney, "History," p. 401.

[57] T. B. Buell, The Quiet Warrior: A Biography of Admiral Raymond A. Spruance (Annapolis: Naval Institute Press, 1974), pp. 239-40; Reynolds, Admiral Towers, pp. 426-441.

Instead, Smith was directed to report to Vice Admiral William F. Halsey, Jr., who directed that STAG-1 proceed to the Russell Islands. In a demonstration witnessed by Rear Admiral E. L. Gunther and Major General Ralph Mitchell, they launched four TDR-1s against a Japanese merchant ship beached off Cape Esperance on 30 July 1944, scoring two hits and two near misses. Smith returned to Hawaii with films and documentation of the trial, hoping to persuade Towers to incorporate STAG-1 into war operations. However, Towers warned Smith to expect orders for STAG-1 to return stateside.[58]

Smith had left his Chief of Staff, Commander Robert F. Jones,[59] in charge of STAG-1 when he returned to Hawaii to plead for further evaluation. Jones was able to delay the return of the missile unit for 30 days, until further operational testing had been completed.[60] Between 26 September and 26 October 1944, STAG-1 launched 46 TDR-1 missiles against Rabaul and Bougainville from Stirling and Green Islands. Only 24 of the missiles reached their target, producing mixed results for the effort.[61] On their return to the United States, Commodore Smith and STAG-1 learned that Admiral King had canceled their program on 8 September 1944.[62]

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[58] Fahrney, "Birth," p. 59; Fahrney, "History,", pp. 417-421; Werrell, Evolution, p. 26.

[59] This is the same officer who had been involved in Project Dog earlier. Jones participated in efforts develop cruise missiles since 1936, when he came to NAF as a project engineer. Fahrney, "History," pp. 215, 227-228.

[60] Permission for the combat employment of the drones was granted by Commander South Pacific: Fahrney, "History," p. 404.

[61] Fahrney, "Birth," p. 59; Trimble, Wings, pp. 266-268.

[62] Fahrney, "History," p. 414.

King's decision reflected both Tower's continuing opposition to the assault drone project and recommendations from the Deputy Chief of Naval Operations (Air). Opposition to Projects Dog and Fox primarily originated from within the staff of the DCNO (Air), particularly from Captain Harry B. Temple, who had arrived in Washington in February, 1944. Captain Temple believed that assault drones would occupy space on carriers that was better used for aircraft, and strongly urged Admiral King to cancel the cruise missile effort.[63]

Fahrney attributed much of the program's lack of success to delays in operational evaluation and hostility on the part of certain flag officers (especially Towers). But he also faults the selection of the TDR-1 drone as the project vehicle, arguing that their poor flight characteristics limited the project's impact.[64]

Political Aspects. The cruise missile zealots, the officers who wholeheartedly supported and defended Projects Dog, Fox, and Option include Fahrney, Jones,[65] Taylor, and Smith. Unlike other zealots, however, Fahrney apparently never committed himself to the extend that his career depended upon the success of the cruise missile. Commander L. C. Stevens, head of BUAER R & D was an ally of Fahrney and an

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[63] Bruins, "Naval Bombardment Missiles," pp. 100-104.

[64] Fahrney, "History," pp. 424-427. With evident black humor, Fahrney labelled this section "Alabi and Goodbye."

[65] Fahrney commends Jones, writing that "As the years have proved, he was not easily deterred by his seniors or juniors in any action he deemed just and proper to take. He did more than any other officer to make the Navy acutely conscious of the importance of the radio controlled aircraft concept, both for antiaircraft defense of the fleet and for offensive applications to missiles." Fahrney, "History," p. 252.

advocate for cruise missiles.[66] These officers formed vertical alliances with a number of flag officers. Fahrney initially received support for his assault drone projects from Admiral Claude Bloch, the Commander in Chief of the US Fleet.[67] Projects Fox and Option had the strong support of two successive CNOs, Admiral Stark and Admiral Ernest J. King. Admiral Frederick J. Horne, the Vice Chief of Naval Operations, also favored the program. Vice Admiral Raymond Spruance's vertical alliance with Smith facilitated the limited operational evaluation of Project Option's missile. Rear Admiral John Towers is remembered for his opposition to the operational evaluation of the TDN-1 assault drone, but his early support for cruise missile research and development under Project Fox must not be neglected. Nevertheless, Fahrney and Smith resented the opposition of Towers and Captain Temple, which they believed hampered the progress of cruise missile development.[68] Admiral King canceled the program on 8 September, 1944, but that decision apparently reflected the poor performance of the TDR-1s in combat, the impression that cruise missiles were carrier weapons that competed with manned aircraft for space, and the growing focus on the more advanced Gorgon missile.[69]

As in the case of the Aerial Torpedo, senior Navy officials expected Fahrney's cruise missiles to be available for combat after very little research and development,

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[66] Fahrney, "History," p. 312.

[67] Friedman, US Naval Weapons, p. 215.

[68] Fahrney, "History," pp. 431-432.

[69] Fahrney, "Genesis," p. 38.

perhaps as early as 1943. When encouraging test results were obtained early in the R & D process, the Vice Chief of Naval Operations, Vice Admiral F. J. Horne, responded by requesting a substantial increase in cruise missile production.[70] Those orders were scaled back and then dropped when operational evaluation of the aircraft failed to demonstrate the missile's efficacy.

**Project Aphrodite, 1944**

In June of 1944, the U.S. Army initiated Project Aphrodite as an ad hoc measure to suppress German missile attacks on Great Britain.[71] The plan was to employ old B-17s, packed with explosives and piloted by radio control, to destroy German launch sites. The U.S. Navy joined the program to provide expertise in radio-controlled, television-guided flight. The Navy program, however, employed the PB4Y aircraft (the maritime patrol version of the B-24 Liberator bomber) and utilized a remote television system for piloting the aircraft. The radio control mechanisms were still sufficiently primitive that safety considerations required pilots to get the bomber airborne. Once aloft, the crew would parachute to safety in England while the bomber was directed to its target across the English Channel.[72]

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[70] N. Friedman, US Naval Weapons: Every Gun, Mine and Torpedo Used by the US Navy from 1883 to the Present Day, (Annapolis: Naval Institute Press, 1982), p. 216.

[71] W. F. Trimble, Wings, p. 299; J. Olsen, Aphrodite: Desperate Mission, (New York: G. P. Putnam's Sons, 1970), pp. 25-57.

[72] Werrell, Evolution, p. 32.

In 1943, Captain Oscar Smith proposed that bombers could be employed as drones, using a pilot for takeoff and radio-controlled flight for the mission. Rear Admiral J. S. McCain, Chief of the Bureau of Aeronautics, disapproved the project on 8 November 1943, on the grounds that planes should not be taken out of service until the drone concept had been proven.[73] Evaluation of a drone bomber project was also undertaken at the Naval Aircraft Factory, Philadelphia, on 21 March 1944, at the request of Captain H. B. Temple, Director of the Special Weapons Section in the Office of the Deputy Chief of Naval Operations for Air. As conceptualized, the project involved modifying PB4Y aircraft for use as assault drones. However, Temple later recommended the project not be pursued.[74] Temple argued that the project was beyond the Navy's scope of operations, and Admiral E. J. King, Chief of Naval Operations, accepted his recommendation on 27 May 1944. However, interest in attacking heavily defended German targets led to the project being reopened on 24 June, and the drones were ready for deployment by 3 July.[75]

Special Attack Unit 1 (SAU-1) was formed on 1 July under the command of Commander James A. Smith[76] and the unit shipped out for England in early July.[77]

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[73] Fahrney, "History," pp. 406-407.

[74] Trimble, Wings, p. 299.

[75] Fahrney, "History," pp. 408-9.

[76] Smith had previously been the Commanding Officer of STAG-3.

[77] Trimble, Wings, p. 300. Fahrney gives the date of establishment as 6 July: "History," p. 409.

In effect, Project Aphrodite went directly from conceptualization to deployment with minimal R & D or operational evaluation.

The first Aphrodite missions were conducted on 4 anu 6 August, 1944, using a modified version of the Army Air Corps' AZON glide bomb control apparatus developed by Major Henry J. Rand.[78] Four B-17's, stuffed with explosive, took off from Fersfield Airfield, northeast of London, and their crews began setting the autopilot and arming the explosives. Three of the air crews successful bailed out of their aircraft but the fourth crashed with its pilot aboard. The remaining drones were guided toward their targets by mother aircraft. German defenses shot down one of the three drones and the last two missed their targets, one by 500 yards and the other by 1500 yards. Two days later, two additional drones were launched, but both crashed before reaching their target area. Lieutenant General James Doolittle canceled that phase of the program immediately and directed that future operations be conducted with the Navy's guidance system.[79]

Lieutenant Joseph P. Kennedy, Jr., the son of the former U.S. Ambassador to the United Kingdom and elder brother of the future president, John F. Kennedy, piloted the first U.S. Navy mission, codenamed ANVIL.[80] The executive officer of Special Attack Unit 1, Lieutenant Wilford "Bud" Willy accompanied Kennedy on the initial flight to arm the explosives. The bomber (codenamed "Zootsuit Black") took off on 12 August, 1944, but exploded only minutes into the flight, before the two officers were able to leave the

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[78] Olsen, Aphrodite, pp. 23-25.

[79] Olson, Aphrodite, pp. 94-170.

[80] Trimble, Wings, p. 300.

aircraft. The cause of the premature explosion has never been determined with any degree of confidence, but the problem has been attributed to a faulty fusing circuit.[81]

A second ANVIL mission was conducted the following month, on 3 September 1944, with better results. The drone bomber was successfully guided toward its target and veered off only at the last moment after the aircraft was struck by flak. The poor quality of the TV picture transmitted to the mother plane also caused difficulties.[82] The Navy was dissatisfied by the overall results of the program and disbanded it immediately thereafter.[83]

The Army Air Corps continued with Project Aphrodite until early 1945, when it was canceled by General Spaatz. Late in 1944 the Army Air Corps leadership abandoned the concept of precision guidance weapons for strongly defended targets, and turned to using the drones as terror weapons against German cities. Subsequent flights demonstrated that the bombers were not adequately handled by the radio remote control, too susceptible to weather conditions, and too vulnerable to flak.[84]

Commodore Smith recommended flying B-24 drones against the Japanese mainland, arguing that large numbers of B-24s would become available after the defeat of Germany. However, this recommendations were not approved.[85]

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[81] Olsen, Aphrodite, pp. 237-253; Fahrney, "History," pp. 413-414.

[82] Werrell, Evolution, p. 32.

[83] Trimble, Wings, p. 301.

[84] Werrell, Evolution, p. 35.

[85] Fahrney, "History," pp. 428-429.

Political Aspects. The naval portion of Project Aphrodite developed (and ended!) very quickly, and it is difficult to discern whether it was envisioned as an operational evaluation of a warfare concept or simply a short-term wartime expediency. The allocation of personnel and resources to the project clearly indicates that the project had the support of senior naval leadership. The limited patience demonstrated by Navy leadership following the early difficulties suggests the project was only an expediency. Commodore Oscar Smith again emerges as the zealot responsible for promoting the project within the Navy, and Captain H. B. Temple serves again as his counterpart, the doubter. On the Army side, Major General E. Partridge, Commanding General of the Third Bombardment Division, was assigned personal responsibility for Project Aphrodite. Project Aphrodite was actively supported by Lieutenant General Doolittle, Commanding General Eighth Air Force, Lieutenant General Spaatz, Commanding General U. S. Strategic Air Forces in Europe, and General H. H. Arnold, Commanding General of the U.S. Army Air Force.[86]

### The Gorgon Missile, 1943-1950

Conceptualization. On 19 July 1943, the Bureau of Aeronautics approved a proposal from Commander D. S. Fahrney and I. H. Driggs, a civilian researcher at BUAER, to develop a small, jet-powered, guided missile with an anti-ship mission.[87]

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[86] Olsen, Aphrodite, pp. 26, 152.

[87] Fahrney indicates he conceived of the program in 1939 and initiated design work design working 1940: "History," p. 510.

The project was assigned to the Naval Aircraft Factory, Philadelphia. Lieutenant M. B. ("Molt") Taylor was designated as the project officer.[88] Driggs was the designer and he developed plans for a small missile of approximately 750 lbs (340 kilograms) with a warhead of 50-100 lbs (22-45 kg). The missile would have a top speed of approximately 500 mph (800 km/h). The project's priority was raised on 19 October 1943, and BUAER requested an estimate of the manufacturing cost of 50 Gorgon missiles. BUAER also requested plans for a rocket-powered version of the Gorgon, presumably because the turbojet engine's development was encountering delays.[89]

Research and Development. Subsequently, BUAER and the Naval Air Material Command (NAMC), the parent command of the Naval Aircraft Factory (NAF), decided to pursue two different airframes for the Gorgon missile. One airframe would have a conventional wing and tail design while the second would employ a canard, with the control surfaces ahead of the wing. As a consequence of these decisions, a whole family of Gorgon missiles were soon under development.[90] The Gorgon II-A and -B missiles were both canard-configured, with rocket and turbojet engines, respectively. The Gorgon III missiles had the conventional configuration, with the A model rocket-powered and the B model turbojet-powered. The first Gorgon IIs were delivered for testing in September, 1944, and the first Gorgon IIIs followed a month later.[91]

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[88] Fahrney, "Genesis," pp. 34-39, 53; Fahrney, "History," p. 477.

[89] Trimble, Wings, pp. 273-274.

[90] Two other members of this family of missiles, Gargoyle and Little Joe, are not discussed here as they were rockets. See Fahrney, "History," p. 510.

[91] Trimble, Wings, pp. 274-276.

A number of guidance systems were also envisioned for the Gorgon missile. Television, active and passive radar, infra-red, and sonic homing systems together with radio remote-control were under development at the Naval Aircraft Factory.[92] Initially the missile was intended for a diverse range of roles, including shore bombardment, anti-ship, and anti-aircraft missions. However, toward the end of the war the developers increasingly envisioned the primary role for the missile as shore bombardment. Presumably, this view was influenced by the attrition of Japanese naval assets and the prospect of an invasion of the Japanese home islands sometime in 1946.[93]

Early tests of the Gorgon missiles produced uneven results. The rocket-powered models proved to be astonishingly fast but difficult to control. After initiation of the powered testing phase, on 2 April 1945, Rear Admiral L. B. Richardson, Assistant Chief of the Bureau of Aeronautics, directed that the Gorgon family be expanded further to include a model III-C. The new model was rocket powered, similar to the III-A model, but had a more powerful engine. (Some time later, a II-C model, powered by a pulse-jet, was also added to the program. The II-C was redesignated the KGN-1 in October, 1945.) Shortly thereafter (April, 1945), Rear Admiral Ramsey, Chief of the Bureau of Aeronautics, revised the program's goals. Thereafter, Project Gorgon was envisioned as an engineering development program for high speed missiles.[94]

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[92] Fahrney, "Genesis," p. 39.

[93] Trimble, Wings, p. 280.

[94] Trimble, Wings, pp. 278-279.

In mid-1945, Project Gorgon began to encounter resistance from Rear Admiral D. Royce, Commander of the Naval Air Material Center (NAMC). Royce believed the missile development program would interfere with other important projects at NAF. His concern was not unreasonable, as production of the II-C model at NAF was expected to grow to 200 per month within the forthcoming year. However, the growing production of Gorgon II-C missiles was brought to a standstill by the unexpected end of the war, on 2 September, 1946. The one Gorgon model that continued in development was the TD2N, a target drone variant of the Gorgon missile. However, difficulties in development led to cancellation of that program on 12 March 1946.[95]

There were additional members of the Gorgon family developed after the war. Martin constructed the Gorgon IV (KUM-1) and delivered eight of these ramjet-powered missiles to the Navy. The Gorgon IV was successfully flown in November, 1947.[96] The Pollux missile, developed and built by the Naval Air Development Station, was similar to the Gorgon II-C, but the wings were swept back and the pulsejet was mounted under the fuselage.[97] The entire Gorgon program was canceled in February, 1951, following the last test of a Pollux missile on 1 December, 1950.[98]

Political Aspects. Gorgon zealots include D. S. Fahrney, M. Taylor, and I. H. Driggs. The Gorgon missile program had the continuing support of senior naval

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[95] Trimble, Wings, pp. 283-284.

[96] Werrell, Evolution, pp. 113; Fahrney, "History," p. 499.

[97] Fahrney, "Genesis," pp. 39, 53.

[98] Werrell, Evolution, p. 113.; Fahrney, "Genesis,", p. 53; Fahrney, "History," p. 509.

personnel, including the Chief of Naval Operations, Admiral Ernest J. King and his successor Admiral Chester Nimitz, and the Chiefs of the Bureau of Aeronautics, Rear Admirals John H. Towers, John S. McCain and D. Ramsey.

## Project Taurus[99]

During the post-war era, especially before the limited wars in Korea and Viet Nam, the nature of warfare appeared to have been forever changed by the advent of the atomic bomb. Many naval leaders believed the future of the Navy depended upon forging a nuclear role for naval forces. The lack of another nation's navy to challenge the U.S. in the post-war era magnified these concerns. The biggest technical obstacle to naval nuclear forces was the large size and weight of primitive atomic bombs. The Navy's AJ-1 Savage (manufactured by North American) was the only bomber large enough to carry the early bombs yet still land and take off from carriers. The AJ-1 had a range of 800 nm.[100]

Captain D. S. Fahrney proposed a drone version of the AJ-1 bomber that would have a range of 1,400 nm in January 1946. (The additional range was obtained by foregoing the return trip.) His proposal was expanded by other engineers at BUAER and Project Taurus, as it was designated, entered research and development in 1947. Like Project Option's assault drones, Taurus would employ aircraft that would be radio-

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[99] This Project Taurus should not be confused with the Taurus tactical shore bombardment missile that was briefly pursued during the 1960s: See Friedman, US Naval Weapons, pp. 227-228.

[100] Werrell, Evolution, p. 114.

controlled from ships or other aircraft. Initial R & D began with F6F-3K aircraft (because the AJ-1 was not yet available) but was canceled in 1948 after Rear Admiral Dan Gallery decided that missiles would not supplant pilots in warfare.[101] Subsequent work focussed upon the Regulus cruise missile, that was designed to carry the large payload necessary for contemporary atomic warheads.

### Project Derby: V-1, JB-2, and Loon, 1944-1953

Conceptualization. In July 1944, the Army Air Force returned more than a ton of German V-1 components to the United States. Using those parts as guides, Army aeronautical engineers quickly fabricated 13 copies of the German cruise missile. The Americanized V-1 was designated the JB-2. At the same time, a recommendation went forth to General Arnold recommending U.S. production of the JB-2. In August, 1944, General B.E. Myers ordered 1,000 JB-2s. Another order for 1,000 of the JB-2 cruise missiles was placed in December 1944. Army Air Force planners envisioned production of 1,000 missiles per month by April of 1945, rising to 5,000 per month by June, 1945.[102] The extraordinary numbers of missiles were intended to subdue the Japanese homeland during the anticipated final stages of the war.

The German V-1 possessed no capability for external guidance. Perhaps as a consequence of the primitive internal guidance system and the lack of any extrinsic

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[101] Werrell, Evolution, p. 114; Fahrney, "History," pp. 1150-1155.

[102] Werrell, Evolution, p. 63.

guidance mechanism, the V-1s accuracy was notoriously poor. The Army was able to improve the missile's accuracy by adding a radar guidance system.[103]

At the instigation of the Bureau of Aeronautics, the U.S. Navy proposed to evaluate the employment of JB-2 cruise missiles on escort carriers. Admiral King, the Chief of Naval Operations, requested 51 JB-2 missiles from the Army for test purposes.[104] The Navy redesignated the missile as the Loon and commenced evaluating escort carriers, landing craft (LST), and submarines as potential Loon platforms.[105]

Following the unexpectedlu sudden end of the war, the Operations Research Group recommended in October 1945 that the Navy institute a program to develop submarine-launched nuclear missiles. The November, 1945, Submarine Officer's Conference echoed that recommendation, supporting development of a shore bombardment role for the submarine force employing nuclear missiles. This was envisioned as a means of substantially enhancing the capabilities of submarines and extending the Navy's striking power inland. Not inconsequentially, acquisition of nuclear

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[103] Werrell, Evolution, pp. 65-67.

[104] Bruins, "Naval Bombardment Missiles," p. 129, indicates that the Navy eventually received 351 JB-2 missiles from the Army. D. K. Stumpf, "The Regulus Cruise Missile: A Forgotten Weapons System: A Complete History of Chance-Vought's Regulus I and II," Unpublished Manuscript, December 1993, p. 9, states that 100 additional Loon missiles were manufactured by Republic Aviation.

[105] The Loon missile also received the designations of KUW-1 and LTV-2: Stumpf, "Regulus Cruise Missile," pp. 9-10.

missiles would also guarantee the submarine force a significant role in the post-war Navy.[106]

Research and Development. Shortly thereafter, the Secretary of the Navy, James Forrestal, and Chief of Naval Operations, Fleet Admiral Nimitz, authorized BUSHIPS, BUORD, and BUAER to initiate a coordinated program of missile development between the three bureaus. The initial phases of that program were focussed on the Loon cruise missile.[107] However, the Loon program was not intended to produce an operational weapons system. Instead, it was a research and development effort in support of subsequent systems, especially the Regulus missiles.[108]

Operational Evaluation. The first Loon launch was conducted 7 January 1946, at the Naval Air Missile Testing Center (NAMTC), Pt. Magu. Shortly thereafter (March, 1946), the Secretary of the Navy approved the modification of two Balao-class submarines, U.S.S. Cusk (SS-348) and U.S.S. Carbonero (SS-347), for cruise missile operations. Cusk was the first boat modified, at Mare Island Naval Shipyard, and was redesignated SSG-348. On 18 February 1947, submarine launches of the Loon missile began and the first successful flight was recorded on 7 March 1947.[109] Additional

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[106] Stumpf, "Regulus Cruise Missile," p. 8; Weir, Forged in War, pp. 230-232; Bruins, "Naval Bombardment Missiles," pp. 130-131.

[107] G. E. Weir, Forged in War: The Naval-Industrial Complex and American Submarine Construction, 1940-1961 (Washington D.C: Naval Historical Center, 1993). pp. 231-232.

[108] Weir, Forged in War, p. 233.

[109] Werrell, Evolution, pp. 68-69.

submarine launches of the Loon continued through the end of 1949, and in January of 1949 the USS Norton Sound (AVM-1) launched one missile.

The Loon missile was subjected to limited, but intensive operational evaluation during Project Pounce, in 1949. Cusk and Carbonero sortied from the West coast and traveled undetected to Hawaiian operating areas, where they both successfully launched their Loon missiles.[110] Two years later, Cusk and Carbonero conducted a simulated cruise missile attack on San Diego. Cusk surfaced, launched a missile, and handed control to Carbonero without being detected by the opposing forces.[111] These exercises demonstrated the inherent capabilities of submarine-launched cruise missiles. Commander John S. McCain, Jr., concluded his evaluation of the Loon missile in Project Pounce with the words: ". . . operations conducted during this period definitely have proven that the use of guided missiles from submarines as an offensive weapon is a progressive step in the expanding study of naval warfare."[112]

Guidance system research and development was an important aspect of Project Derby. The Loon's guidance system consisted of an on-board autopilot linked to a radio remote-control device. The launching submarine could control the missile within line-of-sight or pass control to another submarine or an aircraft. Two submarines could control the missile over a range of 130 nautical miles. However, the guidance system was widely recognized to be inadequate for targeting purposes. Development of the next generation

[110] Stumpf, "Regulus Cruise Missile," pp. 10-11.

[111] Stumpf, "Regulus Cruise Missile," p. 14.

[112] Quoted in Stumpf, "Regulus Cruise Missile," p. 11.

of guidance system, Trounce, began with Loon missiles as part of the research and development effort for the Regulus I missile. Loon missile launches continued through 1951 and 1952 in support of Trounce development. Following the end of Project Derby on 1 January 1953, Loon missile launches continued to maintain missile proficiency and to expend the existing stock of weapons. The final Loon launch was on 11 September 1953.[113]

Political Aspects. The Loon program was initiated and controlled by submarine officers. At the end of World War II, submarine officers were already looking ahead to the next major conflict. In their vision of future war, guided missile submarines could be enormously powerful weapons. Both the 1945 Submarine Officer's Conference and the Operations Research Group recommended development of missile-firing submarines.[114] The most vocal and energetic proponent of the new submarine force was Captain Thomas B. Klakring, himself a submarine officer.[115] Loon had the support of senior naval leaders, including the Secretary of the Navy Forrestal, the Chief of Naval Operations, Fleet Admirals Ernest J. King and his successor, Chester Nimitz. Officers of the submarine community strongly supported Project Derby as a means of gaining a strategic role for the post-war Navy.[116] The program was never intended to produce

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[113] Stumpf, "Regulus Cruise Missile," pp. 14-16.

[114] Bruins, "Naval Bombardment Missiles," pp. 122-125.

[115] Bruins, "Naval Bombardment Missiles," p. 127.

[116] Stumpf, "Regulus Cruise Missile," p. 8; Weir, Forged in War, pp. 230-232.; Bruins, "Naval Bombardment Missiles," pp. 130-131.

an operational missile, hence there was no failure to deploy the weapon. The program ended only to make way for its successor, the Regulus cruise missile.

### Korean War Drones, 1950-1953

In an operation reminiscent of Project Aphrodite, six F6F-5K Hellcat target drones were employed as cruise missiles during the Korean War. Beginning in January, 1952, testing and evaluation of target drones for assault roles began at Pt. Magu. Operations began with the constitution of Guided Missile Unit NINETY (GMU-90) in the summer of 1952, under the command of Captain Robert F. Jones.[117] GMU-90 shipped out for Korea in July. By late August, the unit had shifted to USS Boxer (CV-21) in preparation for launching their attack. Each drone was controlled by two mother aircraft after launching from Boxer. In six missions, GMU-90 attained one hit, four misses, and the final drone crashed after encountering mechanical difficulties.[118] Apparently Navy leadership was not impressed with the results obtained with the assault drone project because active operations ceased thereafter and efforts were devoted instead to Regulus.

[117] This was the same officer who, as Commodore Smith's Chief of Staff for STAG-1, conducted cruise missile assaults against Japanese positions on Rabaul and Bougainville in 1944.

[118] Bruins, "Naval Bombardment Missiles," pp. 205-208. On page 211, Bruins indicates there were 16 missions, but does not elaborate.

## Regulus, Rigel, and Triton, 1947-1964

Conceptualization. Following the end of the Second World War, the Bureau of Aeronautics attempted to interest aircraft manufacturers in guided missile technology.[119] As part of this effort, Chance-Vought received a study to develop concepts and designs for a short range, surface to surface cruise missile in June, 1946. The following year, in June 1947, Chance-Vought submitted a proposal for research and development of a subsonic cruise missile for naval shore bombardment.[120] The proposed missile would be relatively economical, because the test models could be recovered and reused.

Research and Development. This proposal led to the conclusion of a contract between the Navy and Chance-Vought, on 23 December 1947, to build the first test version of the Regulus XSSM-N-8 cruise missile. This contract was expanded on 20 September, 1948, to include production of 30 test missiles. The first Regulus missile was completed in November, 1949.[121] Shortly thereafter, Admiral Gallery requested that the Navy develop a nuclear warhead for the Regulus I missile.[122]

Progress on the Regulus project was complicated by the apparent replication of the Army's Matador missile and the Navy's Regulus programs. The Department of

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[119] Fahrney headed this effort, which was unexpectedly challenging because the aircraft manufacturers expected severe post-war reductions in military R & D. See Fahrney, "History," pp. 1126-1129; Stumpf, "Regulus Cruise Missile," p. 20.

[120] Fahrney, "History," pp. 1173-1174.

[121] Stumpf, "Regulus Cruise Missile," pp. 19-26.

[122] Friedman, US Naval Weapons, p. 218.

Defense's Research and Development Board impounded funds for the two projects on 10 May 1949 and directed that the programs be combined under the direction of the Navy. However, the Navy and Air Force were able to argue the merits of both programs and their projects proceeded independently.[123]

The Regulus test program was established at the Naval Air Missile Test Center (NAMTC) Pt. Magu on 4 January 1949, although the initial testing was done at Edwards Air Force Base, in California's Mojave Desert. The first Regulus flight occurred on 22 November 1950. Unfortunately, that flight ended quickly when the test vehicle crashed. The first successful flight followed on 29 March 1951. After a long series of test flights at Edwards, operations shifted to Pt. Magu on 1 December 1951. Initial operations involved launching the Regulus from shore and controlling the missile from USS Cusk (SSG-348), which was stationed offshore.

Operational Evaluation. After extensive testing, the first shipboard launch of the Regulus cruise missile was from the USS Norton Sound (AVM-1) on 2 November 1952. The launch was a success and the missile was recovered on San Nicolas Island. The first launch from a warship at sea was from USS Princeton (CV-37) on 16 December 1952. The first Regulus launch from a submarine followed the next year, when USS Tunny (SSG-282) launched a Regulus I on 15 July 1953.[124] On 19 November 1957, USS Helena (CA-75) launched a Regulus I missile and controlled it for 112 miles. Two submarines successively took control of the missile and guided it for an additional 160

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[123] Werrell, Evolution, pp. 113-115; Stumpf, "Regulus Cruise Missile," pp. 25-27, 36.

[124] Stumpf, "Regulus Cruise Missile," pp. 30-68.

miles, directing the missile to within 150 yards of the target after 272 miles of total flight, achieving an accuracy that was more than adequate for nuclear warfare.[125]

Deployment. Regulus was designed to deliver nuclear warheads to enemy territory. During early testing of the missile, Regulus I was flown with dummy W-5 atomic warheads. Two units, Submarine Weapons Assembly Teams FIVE and SIX were stood up and deployed in June, 1953. These units were tasked with assembling the warheads and installing them in the missiles in the event of a nuclear war. Deployment of these units, together with the provision of W-5 warheads, provided the Navy with its first nuclear cruise missile capability.[126]

Regulus I missiles were deployed on several cruisers for nuclear deterrence patrols. The first deployment was on board USS Los Angeles (CA-135) beginning in February, 1955. Other cruisers that deployed with Regulus I include the USS Helena (CA-75), USS Toledo (CA-133), and USS Macon (CA-132). Cruiser deployments with Regulus I continued until 1961.[127]

The first carrier deployment of Regulus I missiles with nuclear warheads was on board USS Hancock (CV-19) on 5 August 1955. Hancock deployed to the western Pacific with four missiles.[128] During the deployment, there were several Regulus flights as part of the overall operational development program. There were five additional

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[125] Friedman, US Naval Weapons, p. 217.

[126] Stumpf, "Regulus Cruise Missile," pp. 67-71.

[127] Stumpf, "Regulus Cruise Missile," pp. 160-170

[128] Stumpf, "Regulus Cruise Missile," pp. 142-145.

carrier deployments of Regulus I, with the final deployment of missiles embarked on USS Lexington (CV-16) when she deployed on 17 July 1958.[129] In the meanwhile, test launches of Regulus I missiles continued from carriers, cruisers, and submarines.

Adaptation of the Regulus I missile to submarines began with the conversion of USS Tunny (SS 282) to a guided missile submarine (SSG) in 1953. Other submarine conversions followed, including USS Barbero (SSG-317) in 1955, USS Greyback (SSG-574) and USS Growler (SSG-577) in 1958 (Greyback and Growler's conversion began while still under construction: before the conversion was complete they were further modified for the larger Regulus II missile.[130]) The Regulus hanger on Greyback and Growler were located in the hull, rather than mounted externally aft of the sail as on older submarines. A single nuclear submarine, USS Halibut (SSGN-587) was designed and built as a Regulus-launching submarine. Halibut was commissioned in 1960.[131] The first launch of a Regulus I missile from a submarine was from Tunny in July, 1953. Tunny also conducted the first submarine strategic strike deterrence patrol, beginning 18 July 1958. Submarines conducted regular scheduled deterrence patrols from 1959 through 1964, when they were relieved by Polaris submarines. The final Regulus deterrence patrol ended 11 July 1964 when Halibut returned to Pearl Harbor after a short deployment.[132]

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[129] Stumpf, "Regulus Cruise Missile," p. 152.

[130] Stumpf, "Regulus Cruise Missile," pp. 231-234, 248.

[131] Stumpf, "Regulus Cruise Missile," pp. 261-269.

[132] Stumpf, "Regulus Cruise Missile," pp. 173-201, 269.

**Rigel and Triton.** As development continued on the Regulus program, the Navy began planning for subsequent cruise missiles with longer ranges and higher velocities. In early 1948, plans called for a Rigel missile to be operational in 1955 and a Triton missile for 1960. Both Rigel and Triton were to be supersonic missiles.[133]

Grumman had begun design work on the Rigel missile in the late 1940's, and had constructed a 1/6th scale model by March, 1950. However, the early test flights of the Rigel models were uniformly unsuccessful. As a consequence of the test results and budgetary constraints, the Navy and Grumman agreed in January, 1952, to allow the production schedule for Rigel to slip five years, to 1960. However, following the election of President Dwight D. Eisenhower later that year, the Rigel program was canceled on 5 August 1953, without a single full-scale test missile ever having been produced.[134] Rigel was replaced by Chance-Vought's Regulus II, a decision that was based in part upon the excessively long catapult required to launch the Rigel missile.[135] Development of Triton, however, remained the Navy's ultimate objective.[136]

Unlike the Regulus and Rigel missiles, the Triton program was sponsored by the Bureau of Ordnance.[137] The Triton missile entered development in 1955 but was canceled two years later, in September, 1957. Triton (designated XSSM-N-2) was

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[133] Werrell, Evolution, p. 117; Bruins, "Naval Bombardment Missiles," pp. 236-239.

[134] Friedman, US Naval Weapons, p. 218.

[135] Friedman, US Naval Weapons, p. 217.

[136] Bruins, "Naval Bombardment Missiles," pp. 236-239, 515.

[137] Friedman, US Naval Weapons, p. 218.

envisioned as the ultimate cruise missile: supersonic, 2,000 mile range, guided by a terrain-matching, side-scanning radar system. The cancellation preceded any difficulties in development, and reflected the extreme budgetary constraints of the time.[138] At the time, the only cruise missile still under development was Regulus II.

Political Aspects. The Regulus I, Rigel, and Triton missiles had the full support of the Guided Missiles Division of the Office of the Chief of Naval Operations. The submarine force also supported the cruise missile program, although by the late 1950's it was becoming clear that the Polaris program would produce a more efficient strategic weapon. In losing to Polaris as the strategic weapon of choice, supporters of cruise missiles attempted to assign a tactical role for their weapons. However, cruise missiles could not replicate the results obtained with manned aircraft in a tactical role.[139] These comparisons left the fledgling cruise missile programs vulnerable in times of economic stress. But it is important to emphasize that the cancellations reflected economic stresses of the late 1950's, and not the potentials inherent in the weapons.

### Regulus II, 1952-1958

Conceptualization. Chance-Vought's Regulus II (XRSSM-N-9) was a long range supersonic missile that substituted in Navy planning for Grumman's Rigel missile that was canceled in March of 1953.[140] Chance-Vought had begun design work on the

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[138] Bruins, "Naval Bombardment Missiles," pp. 279-310, 517; Werrell, Evolution, p. 119.

[139] Bruins, "Naval Bombardment Missiles," pp. 307-308.

[140] Werrell, Evolution, p. 117.

Regulus II cruise missile in April, 1952 and received a Navy contract for developing the missile in June, 1953.

Research and Development. As with the Regulus I program, the manufacturer planned to develop recoverable test vehicle that could be reused indefinitely. The first Regulus II missile flew in December, 1955 and was tested with at least partial success in 44 out of 48 attempts. On 16 September, 1958, a Regulus II missile was successfully fired from a submarine, USS Greyback (SSG-574), the only submarine launching attempted with this missile. Another successful sea-launch was conducted from the USS King County (AG 157) on 10 December, 1958. Encouraged by the successful research and development, the Navy signed a production contract for the missile in January, 1958. At the time, the Navy planned to deploy the Regulus II missile on cruisers and a large number of submarines. However, the program was abruptly canceled on 12 December 1958 by Secretary of the Navy Thomas S. Gates.[141] As for Regulus I, the reason for the cancellation was the apparent superiority of the Polaris system in the strategic mission combined with the limited financial support granted the Navy in the late 1950's.

Regulus II missiles that had been procured prior to the program's cancellation were expended in R&D for other systems. On 10 May 1961 a Sea Sparrow III missile successfully intercepted a Regulus II missile in supersonic flight, the first head-on interception of a surface-launched missile.[142]

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[141] Stumpf, "Regulus Cruise Missile," pp. 103-123.

[142] United States Naval Aviation 1910-1980 (Washington D.C: U.S. Government Printing Office, 1981), p. 245.

## Standard Missile

The Standard Missile was developed primarily as a surface to air weapon to replace the older Tartar/Terrier/Talos missile family. Norman Friedman indicates that the standard missile also has a limited, line of sight, surface to surface capability.[143] The capability was pursued as an interim measure during development of the Harpoon and Tomahawk missiles. Admiral Elmo Zumwalt included the surface to surface Standard Missile in his Project Sixty list of top Navy priorities.[144] The first version of the anti-ship Standard Missile, tested in 1971, utilized a passive homing guidance system. A second version with an active homing guidance system was tested in 1973 but never entered production.[145] The Standard Missile is not a cruise missile, employing a rocket motor and ballistic flight, and never possessed a capability for shore bombardment.

## Harpoon, 1965-Present

Conceptualization. The Harpoon cruise missile program was initially conceived by the Naval Air Systems Command as a means to provide maritime patrol aircraft (P-3 Orion) with an extended strike capability against surfaced submarines.[146] McDonnell-Douglas had begun independent development of the missile in 1965. Following the Eilat incident in October, 1967, the Navy signed a study contract with McDonnell-Douglas for

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[143] Friedman, World Naval Weapons, pp. 240-242.

[144] Friedman, US Naval Weapons, p. 231.

[145] Friedman, US Naval Weapons, p. 231.

[146] Friedman, World Naval Weapons, p. 94.

air- and ship- launched anti-ship versions of Harpoon. The contract called for a missile with a 70 km (40 nm) range and a 120 kg (250 lb) warhead. Furthermore, the Navy required that the missile be compatible with existing handling equipment for older missiles.[147]

Research and Development. The Defense Systems Acquisition Review Council (DSARC) approved development of two versions of the Harpoon missile in November, 1970: the AGM-84A air launched missile and the RGM-84A ship-launched version. In June of the following year, contracts for the air frame and guidance system were let to McDonnell-Douglas and Teledyne, respectively. The first air-launched Harpoon missile test was conducted from an Orion aircraft in May 1972.[148] The first surfaced-launched Harpoon test flight occurred on 17 October, 1972, and the first submarine-launched Harpoon test flight followed on 15 November of that year.[149] Full approval for the weapon system development was obtained in July 1973 and the pilot production of 150 missiles was approved a year later.

Operational Evaluation and Deployment. Missile production began in 1975, and operational evaluation was completed in March, 1977.[150] Deployment on surface ships

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[147] Werrell, Evolution, p. 150.

[148] Friedman, US Naval Weapons, p. 211; this might have only been a drop test, as other sources report the first powered flight did not occur until October 1972: R. Meller, "The Harpoon Missile System," International Defense Review, vol. 8, no. 1 (January, 1975) p. 66.

[149] Friedman, US Naval Weapons, p. 211.

[150] Friedman, World Naval Weapons, p. 94; Jane's Naval Weapons Systems 1989 Issue 7 states operational evaluation was completed in June, 1977.

began immediately thereafter. USS Sterret (CG-31) was the first ship to receive production Harpoon missiles.[151] Harpoon was deployed in Orion maritime patrol aircraft two years later, and a version developed for the A-6 Intruder was deployed in 1981.[152] Harpoon missiles were probably responsible for the sinking of some Iraqi ships during the Iran-Iraq war. The U.S. Navy successfully engaged Libyan naval forces with Harpoon missiles on 24-25 March 1986.[153] Today, Harpoon is employed by 20 navies throughout the world.[154]

Subsequent developments of the Harpoon missile have included the SLAM version (AGM-84E) and an extended range model for the Air Force's B-52G bomber.[155]

Political Aspects. Following the Eilat incident (October, 1967), support for the Harpoon program was not difficult to gather.[156] But, even prior to the Eilat's sinking, Captains Worth Bagley and Elmo Zumwalt had sent a memorandum to the Secretary

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[151] Jane's Naval Weapons Systems 1989, Issue 9.

[152] Werrell, Evolution, pp. 150-151; Jane's Weapons Systems 1987-88 (London: Jane's Publishing Company, 1988), p. 488.

[153] Jane's Naval Weapons Systems 1989, Issue 7.

[154] Friedman, World Naval Weapons, p. 93.

[155] F. E. Grosick, P. L. Massey, and M. W. Petersen, "Harpoon Employment in Naval Antisurface Warfare (ASUW)," Unpublished research report, Air University, Maxwell Air Force Base, AL: 1988.

[156] Congressional interest in anti-ship cruise missiles has been reported as another factor responsible for stimulating the Navy's interest in Harpoon: B. Nihart, "Harpoon: Navy's Answer to Soviet Missile Boats," Armed Forces Journal, vol. 108, 16 November 1970, pp. 22-23.

of the Navy arguing that the service needed an anti-ship cruise missile. Secretary of the Navy Paul Nitze agreed in principle to developing a surface to surface naval cruise missile.[157] Development of Harpoon was strongly supported and accelerated by the Chief of Naval Operations, Admiral Elmo Zumwalt. (This is probably one of the few times that a program was both championed and grandfathered by the same officer.) Naval aviators were Harpoon's initial sponsors. Nevertheless, it was the surface warfare community that was responsible for expanding the Harpoon program to include surface- and submarine-launched missiles. Undoubtedly, the Harpoon program appealed to the three major constituencies of the naval officer community (aviation, surface warfare, submarines) because it was a versatile weapon that could be employed to increase the capabilities of each warfare community.

**Tomahawk, 1970- Present**

Conceptualization. The development of the Tomahawk cruise missile can be traced to a 1970 study by the Center for Naval Analysis (CNA) that concluded underwater-launched cruise missiles were technically possible.[158] The CNA study led to the Advanced Cruise Missile (ACM) and Submarine Tactical Antiship Weapon

[157] R. J. Art and S. E. Ockenden, "The Domestic Politics of Cruise Missile Development," R. K. Betts, ed., Cruise Missiles: Technology, Strategy, Politics (Washington D. C: Brookings Institution, 1981), p. 381.

[158] Werrell, Evolution, p. 151; Friedman, World Naval Weapons, p. 43.

System (STAWS) concepts.[159] The Chief of Naval Operations created a new office within NAVAIR to oversee the ACM project.

The new initiative was undertaken at the same time that Harpoon was entering research and development. In effect, the two programs competed for R&D funds. The Chief of Naval Operations, following a recommendation from a review panel, proposed the majority of research and development funding be devoted to an encapsulated version of the Harpoon missile, rather than an entirely new missile. Meanwhile, Secretary of Defense Melvin Laird requested additional funding from Congress for research and development of strategic weapons, including cruise missiles. His action reflected a decision by the Departments of State and Defense as a "bargaining chip" in the negotiations for the Strategic Arms Limitation Treaty II (SALT II) in 1972.[160] The Navy responded to Laird's initiative by requesting that the strategic cruise missile be adaptable for tactical purposes, and dropped the ACM project.[161] However, that change in policy in reality masked the actual ". . . marriage of convenience. . ."[162] between Laird's missile and the Navy ACM. The Navy ACM project, renamed as the

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[159] The STAWS concept was recommended in 1970 by an ad hoc panel chaired by Admiral R. Kaufman, and was quickly adopted by Admiral H. G. Rickover as justification for a new class of nuclear submarines: Art and Ockenden, "Domestic Politics," pp. 385-386.

[160] Friedman, US Naval Weapons, p. 225.

[161] R. Huisken, "The History of the Cruise Missile," R. K. Betts, ed., Cruise Missiles: Technology, Strategy, Politics (Washington, D.C: Brookings Institution, 1981), pp. 85-86

[162] Art and Ockenden, "Domestic Politics," p. 387.

SLCM, continued as an extension of the Department of Defense's Strategic Cruise Missile.

Research and Development. The Navy abandoned STAWS in 1972 but continued research on a Sea-Launched Cruise Missile (SLCM). The Navy formally announced the SLCM program on 2 June 1972.[163] On 17 March, 1973, the Navy awarded a contract to General Dynamics for development of the SLCM airframe. Two years later, McDonnell-Douglas was awarded a contract to develop the TERCOM guidance system. The first Tomahawk flight followed in December, 1976.

Throughout the early phases of research and development the Navy's SLCM (soon to be designated Tomahawk) was effectively in competition with the Air Force's Air-Launched Cruise Missile (ALCM). Department of Defence officials questioned the requirement for separate Navy and Air Force programs, seeking to conserve funds through adopting a common missile for both services or by eliminating one service's requirement. This inter-service conflict lies outside the scope of this paper: R. Huisken provides an excellent review of the Air Force-Navy rivalry for the development of the cruise missile.[164]

In February 1974, the Defense Systems Acquisition Review Council (DSARC) approved a joint USN/USAF cruise missile development program and authorized the award of competitive development contracts.[165] LTV and General Dynamics were

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[163] Jane's Naval Weapons Systems 1989, Issue 11.

[164] R. Huisken, "History," p. 83; R. Huisken, The Origin of the Strategic Cruise Missile (New York: Praeger Publishers, 1981).

[165] Huisken, "History," p. 88.

selected to develop prototypes, and General Dynamics eventually won the contract for the missile.

Operational Evaluation and Deployment. The first test of the land attack Tomahawk cruise missile occurred on 5 June 1976. The first test of the Tomahawk Antiship Missile (TASM) followed six months later, on 7 December 1976. Operational evaluation for the submarine-launched versions commenced in 1981 and the missile was deployed in 1983 in Los Angeles-class submarines.[166] Operational testing and evaluation on Tomahawk missiles on surface ships also began in 1981, and deployment in surface ships was accomplished in 1984. The first surface ship to receive production Tomahawk missiles was USS Comte de Grasse (DD-974).[167]

The conventional land-attack version of the Tomahawk missile (TLAM-C) was employed extensively in combat during Operation Desert Storm in 1991. Nearly 300 TLAM-C were flown against Iraq with a reported success rate of 85 percent.[168]

Tactical/Operational/Strategic Integration. Unlike any of the previously discussed missiles, the Tomahawk presented the unusual difficulties in integrating the new weapon into current concepts of naval warfare.[169] These difficulties reflect, in part,

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[166] Jane's Naval Weapons Systems 1989, Issue 11.

[167] Jane's Naval Weapons Systems, 1989, Issue 11.

[168] Jane's Naval Weapons Systems, 1989, Issue 11.

[169] M. Hura and D. Miller, "Cruise Missile Warfare," U. S. Naval Institute Proceedings, vol. 111, no. 10 (October 1985), p. 97; P. G. Johnson, "Tomahawk: The Implications of a Strategic/Tactical Mix," U. S. Naval Institute Proceedings, vol. 108, no. 4 (April 1982), p. 26; E. Zumwalt and W. Bagley, "Cruise Missile Use Proving Challenge to Navy Strategy," Navy Times, March 7 1983, p. 20..

the tremendous capability of the Tomahawk system and genuine limits on cruise missile warfare, such as the number of missiles loaded out on each platform. At various times, Tomahawk has been presented as a strategic weapon, a theater nuclear weapon, a precision conventional land attack weapon, and an extended-range anti-ship weapon. Of course, Tomahawk is all of these; therein lies the difficulty.

Political Aspects. The Tomahawk cruise missile program benefitted from support from the highest echelons of the U.S. Navy. Early in its development, the Chief of Naval Operations, Admiral E. Zumwalt, pressed hard for a capable, long range SSM for the surface fleet. Zumwalt formed a vertical alliance with Secretary of Defense Laird to promote the development of the long-range tactical cruise missile.[170] Subsequently, Admiral James L. Holloway III, an aviator, presented strong arguments in support of the program.[171] Although a number of authors viewed naval aviators as a "potential source of opposition,"[172] at no time was organized opposition from any of the Navy's warfare communities evident. Robert J. Art and Stephen E. Ockenden have emphasized that Tomahawk's ambiguous role in naval warfare contributed to the lack of opposition. Supporters could always evade critics by keeping the missile's role ambiguous or sidestep opposition by emphasizing other possible roles for the missile.[173]

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[170] Art and Ockenden, "Domestic Politics," p. 387.

[171] Art and Ockenden, "Domestic Politics," p. 392.

[172] Art and Ockenden, "Domestic Politics," p. 389.

[173] Art and Ockenden, "Domestic Politics," pp. 390-393.

# CHAPTER V

## ANALYSIS

The history of Navy cruise missile innovation, outlined in the foregoing chapter and summarized in Figure 2, documents a substantial organizational commitment to the development of cruise missile systems over many years. In the quarter century before the _Eilat_ incident, the Navy pursued a total of eight projects and had active programs in 17 of the 25 years. Thirteen separate cruise missile projects were designated by the U. S. Navy over the past eighty years, and twelve of those projects entered research and development.[1] Nine projects reached the stage of operational evaluation. Of those nine projects, three were eventually deployed to the fleet. Figure 3 shows that many of these projects were initiated during World War II and several of them were continued into the cold war era. Most of the projects were organized within the Bureau of Aeronautics, with the firm support of senior naval aviators, including the Chief of Naval Operations, Admiral Ernest J. King, himself a naval aviator.[2]

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[1] These numbers would be larger still if Projects Dog, Fox, and Option were treated individually.

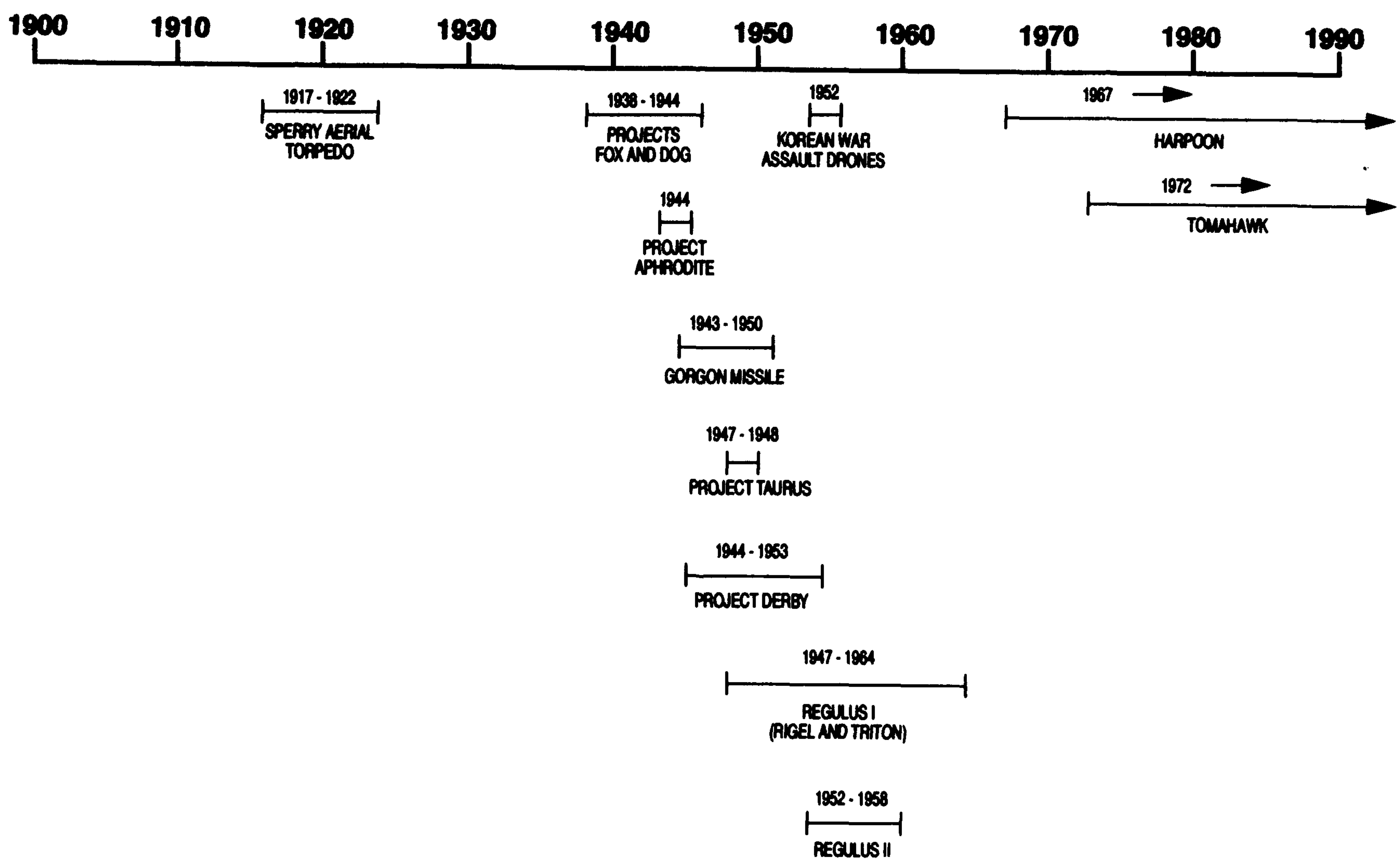
[2] Fleet Admiral E. J. King was a latecomer to the ranks of naval aviation, attending flight school in 1927 as a Captain at the urging of Rear Admiral William Moffett: T. B. Buell, _Master of Seapower: A Biography of Fleet Admiral Ernest J. King_ (Boston: Little, Brown and Company, 1980), pp. 72-76.

## FIGURE 2
## U.S. NAVY PROGRESS IN CRUISE MISSILE INNOVATION

| | CONCEPTUALIZATION | RESEARCH & DEVELOP. | OPERATIONAL EVAL. | DEPLOYMENT |
|---|---|---|---|---|
| AERIAL TORPEDO | X | X | | |
| PROJECTS FOX AND DOG | X | X | X | |
| PROJECT APHRODITE | X | X | X | |
| GORGON MISSILE | X | X | X | |
| PROJECT TAURUS | X | | | |
| PROJECT DERBY | X | X | X | |
| KOREAN WAR DRONES | X | X | X | |
| REGULUS I | X | X | X | X |
| RIGEL | X | X | | |
| TRITON | X | X | | |
| REGULUS II | X | X | X | |
| HARPOON | X | X | X | X |
| TOMAHAWK | X | X | X | X |

94-ADVR46

# FIGURE 3
# TEMPORAL DISTRIBUTION OF NAVY CRUISE MISSILE PROJECTS




94-ADVR47

During the postwar years, the Navy initiated the Regulus I and II, Rigel, and Triton projects in support of the Navy's pursuit of a strategic nuclear mission. Regulus I was successfully deployed and served in the fleet for a decade. Numerous strategic deterrence patrols were conducted by carriers, cruisers, and submarines with Regulus I embarked. Regulus II reached operational evaluation and several submarines were designed and built expressly for this cruise missile. Rigel and Triton did not advance past initial research and development, but that failure to progress reflected technical difficulties with the missiles and not Navy resistance to the programs. The Regulus programs were canceled as the Polaris missile became operational.

Another Chief of Naval Operations, Admiral Elmo Zumwalt, blamed naval aviators for canceling the Regulus cruise missile programs, calling it ". . . the single worst decision about weapons it [the Navy] made during my years of service."[3] He clearly envisioned the Regulus programs as promising tactical systems that could be employed in an anti-ship role. In fact, the Regulus I and II cruise missile programs were canceled by a surface warrior, Admiral Arleigh Burke, who was Chief of Naval Operations in 1959. Berend Bruins' meticulous analysis of the Regulus program demonstrates that Burke's decision to terminate those programs resulted of a confluence of several factors: the demonstrated superiority of Polaris as a submarine-based, strategic system; the flexibility and accuracy of carrier-based aircraft in tactical roles; and the limited financial

[3] E. R. Zumwalt, Jr., On Watch (New York: Quadrangle-New York Times Book Company, 1976), p. 81.

resources available to the Department of Defense in the late 1950's.[4] Clearly, the simplistic view that aviators suppressed weapons, such as Regulus, that could challenge their political dominance within the Navy is incorrect.

Undeniably, there is a perception among the Navy's surface officer community that the Navy was too slow to develop cruise missiles. The roots of this common wisdom probably lies more in a sense of intra-service professional rivalry than historical fact, although some early proponents of cruise missiles were undeniably disappointed with the Navy's perceived failure to promote these weapons.[5] The actual history of Navy efforts to develop a viable cruise missile are poorly known to those outside the arcane field of naval military history. Most of the projects were conducted outside the major officer communities and were subject to security considerations that prevented widespread dissemination of information regarding the missiles. Consequently, the views expressed by officers, even flag officers, of the mainstream warfare communities are often uninformed.

Returning now to the issue of cruise missile innovation, it is clear that, although Admiral Zumwalt,[6] and others,[7] unfairly fault aviators for blocking the development of

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[4] B. D. Bruins, "U. S. Naval Bombardment Missiles, 1940-1958: A Study of the Weapons Innovation Process," Unpublished doctoral dissertation, Columbia University, New York, NY: 1981).

[5] D. S. Fahrney, "The History of Pilotless Aircraft and Guided Missiles," Unpublished Manuscript, Naval Historical Center, 1958, p. 1366.

[6] E. R. Zumwalt, Jr., "High-Low," U. S. Naval Institute Proceedings, vol. 102, no. 4 (April, 1976), p. 55; E. R. Zumwalt, Jr., On Watch, p. 81.

cruise missiles, it does not necessarily follow that Navy leaders made the appropriate decisions regarding the development the Sea-Launched Cruise Missile (SLCM). Was the eventual development of the Navy's cruise missile a 1975 response to a 1960 threat, as one article has suggested?[8] More generally, has the Navy generally succeeded or failed in its endeavors toward cruise missile innovation? If it has failed, are there systematic problems that must be addressed in the future?

These questions necessitate reconsideration of the definition of success in innovation. Some critics, including Admiral Zumwalt, apparently define success as the delivery of a desired technology to the fleet. But this definition is obviously incomplete: unneeded technology confers no benefit while consuming scarce resources.[9] Indeed, this was the entire point of Zumwalt's arguments concerning the "high-low" mix of technologies for the fleet.[10] Innovation is successful when technology, together with the tactics, operational art, and strategy necessary to employ the new technology, is available

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[7] R. J. Art and S. E. Ockenden, "The Domestic Politics of Cruise Missile Development, 1970-1980," R. K. Betts, ed., Cruise Missiles: Technology, Strategy, Politics (Washington D. C: Brookings Institution, 1981), pp. 349-390; D. S. Fahrney, " History," pp. 1094-1097; W. M. McBride, "The Rise and Fall of a Strategic Technology: The American Battleship from Santiago Bay to Pearl Harbor, 1898-1941," Unpublished doctoral dissertation, The Johns Hopkins University, Baltimore, MD:1989, p. 358-9; R. W. Love, Jr., History of the U. S. Navy, 1942-1991 (Harrisburg: Stackpole Books, 1992), p. 644; D. K. Stumpf, "Blasts from the Past," U. S. Naval Institute Proceedings, vol. 119, no. 4 (April, 1993), p. 64; K. P. Werrell, The Evolution of the Cruise Missile (Maxwell Air Force Base: Air University Press, 1985), p. 150.

[8] B. Nihart, "Harpoon: Navy's Answer to Soviet Missile Boats," Armed Forces Journal, vol. 108, 16 November 1970, p. 22.

[9] See T. H. Etzold, "Being Right Too Soon," U. S. Naval Institute Proceedings, vol. 109, no. 1 (January 1983), p. 57.

[10] Zumwalt, "High-Low," p. 55; Zumwalt, On Watch, pp. 72-84.

to the operating forces at the time it is needed: not too early, not too late. Thus, roles, missions, and current concepts of warfare play a fundamental role in determining success in innovation.[11]

## Navy Missions, 1940-1985

Prior to the Second World War, the Navy's perceived mission was to seek out enemy fleets, to defeat them and secure control of the sea, and to embargo enemy countries, thus destroying their commerce. During the Second World War, the Navy mission expanded to include projecting power ashore, through air power and amphibious operations. The Navy's successes during the war, however, carried the potential seeds of the Navy's eventual demise. There were no potentially unfriendly fleets and no prospect of conventional naval combat to justify maintaining a large fleet in the postwar years. Indeed, there is considerable precedent in United States history for massive force reductions following the end of a war. Furthermore, many senior government and military officials believed that nuclear weapons made conventional war obsolete. At the end of the war, the Air Force had a monopoly on the United States' nuclear arsenal and the nation's strategic missions. In the eyes of some senior government and military officials, a coastal defense force would be sufficient for the nation's needs.

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[11] This is an especially complex problem because new technology can alter these roles, missions, and concepts of warfare. Neither the technology nor the concepts of warfare independently determine the other variable, instead, it is the non-linear interaction of these variables (together with other variables, such as the enemy's technology and tactics) that determines the appropriate outcome. For a discussion of non-linear reasoning in warfare, see A. Beyerchen, "Clausewitz, Nonlinearity, and the Unpredictability of War," International Security, vol. 17, no. 3 (Winter 1992/3), p. 59.

Senior Navy officials believed that the future Navy could be justified only on the basis of a nuclear capability. Those same officials fought hard to obtain that nuclear role for the Navy.[12] There efforts were essentially successful politically, but raised important technical issues. Early nuclear weapons were large and extremely heavy. The Navy lacked the means to deliver nuclear bombs or warheads in 1945. Consequently, development of nuclear-capable delivery platforms was given the highest priority in the post-war Navy. Eventually, nuclear weapons designers engineered more compact, lighter nuclear devices. In the meantime, the Navy grappled with the problem of delivering the massive atomic bombs.

Following the Korean conflict and other, less intense actions, it gradually became apparent that nuclear weapons had not made conventional war obsolete. The President repeatedly turned to naval forces, especially the carrier and its associated battle groups, when military action became necessary in support of national objectives.[13] These lessons, combined with the extensive Soviet naval buildup beginning in the 1960's, led the Navy to reprise its older mission as a sea control force.

## Cruise Missiles and the Navy's Missions

The history of naval cruise missile innovation reflects the Navy's changing mission over the past eight decades. In 1917, the Navy's interest in cruise missiles derived from

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[12] V. Davis, Postwar Defense Policy and the U. S. Navy, 1943-1946 (Chapel Hill: University of North Carolina Press, 1962) pp. 190-270.

[13] B. M. Blechman and S. S. Kaplan, Force Without War: U. S. Armed Forces as a Political Instrument (Washington, D.C: Brookings Institution, 1978), p. 529.

its potential as an anti-ship weapon. Naval interest waned as it became clear that the aerial torpedo lacked the accuracy and speed necessary to attack ships at sea. The possible employment of the aerial torpedo for shore bombardment was dismissed as potentially interesting to the Army, but outside the Navy mission. The Navy was willing to invest money in aerial torpedo research and development, but a weapon suitable for the Navy's mission, war at sea, did not materialize. The subsequent decisions not to produce or deploy the weapon were entirely reasonable in the context of the time.

During the early part of the Second World War, cruise missiles were again examined as potential anti-ship weapons (Projects Fox and Dog, Gorgon Missile). As the war progressed, the Navy increasingly sought a balance between anti-ship and shore bombardment missions (Gorgon Missile, Project Option, Project Aphrodite), with the latter mission gaining importance toward the end of the war. By the end of the war, the cruise missile projects were focussed entirely on shore bombardment (Project Derby, Gorgon Missile). This shift in emphasis partly reflected continuing problems in targeting ships at sea. More importantly, seagoing targets were rare toward the end of the war, and the subjugation of the Japanese homeland remained a formidable obstacle to U. S. armed forces. It was this shifting naval mission that influenced the directions of cruise missile development.

Following the unexpectedly sudden end of the war, the emergence of the Soviet Union, a continental power, as the world's second superpower continued to shape the Navy's mission. Shore bombardment, now with nuclear weapons, was the primary focus of naval planners. The Navy sought to succeed in its new atomic role by developing nuclear-capable missiles for the submarine and surface fleet and powerful bombers, large enough to carry the W-5 bomb but still small enough to fly off World War II carriers, for the aviators.[14] The Navy's continued persistence with Project Derby and the investments in the Regulus I, II, Rigel, and Triton missiles ware efforts to meet the new requirement for nuclear-capable missiles. The Regulus program was repeatedly presented to Congress as a strategic program, if only for limited nuclear war.[15] This effort was successful and the missile was developed and deployed. Regulus deterrence patrols were conducted for nine years (1955-1964). The demise of the Regulus program reflected the success of the Polaris program and contemporary financial constraints, not any organizational prejudice toward against cruise missiles.

The emergence of the Soviet nation as a maritime power, beginning in the 1960's, provided the naval rivalry that the U. S. Navy had lacked for two decades. It also revived the need for modern anti-ship weapons. The Eilat incident is often cited as the trigger for Navy cruise missile programs, but naval leaders were actually considering a U. S. Navy cruise missile program before October, 1967. The rapid progress of the Harpoon and Tomahawk cruise missiles are a credit to Navy and civilian weapons specialists. However, the Navy cannot take all of the credit. McDonnell-Douglas had independently

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[14] The aviator's technical problems extended beyond aircraft; they needed aircraft carriers capable of launching these larger bombers. The "Revolt of the Admirals" in 1949 was a response to the Secretary of Defense, Louis Johnson, canceling a new class of aircraft carriers that would be capable of launching these new, larger attack aircraft. See R. W. Love, Jr., History of the U. S. Navy, 1942-1991 (Harrisburg: Stackpole Books, 1992), pp. 319-324; P. R. Schratz, "The Admirals' Revolt," U. S. Naval Institute Proceedings, vol. 112, no. 2 (February 1986), p. 64.

[15] B. Bruins, "Naval Bombardment Missiles," pp. 322-367.

initiated development of Harpoon with company funds.[16] Also, the time had finally arrived when such weapons were technologically possible. The technology of turbojet and turbofan engines was now sufficiently well advanced that efficient, compact engines were available and developments in microelectronics had made the small but sophisticated guidance systems possible.[17]

The Soviet Navy's history of cruise missile development constitutes a heuristic counter-example to the U. S. Navy's experience. The Soviet naval mission in the early cold war was to deny NATO forces sea control and prevent the resupply of NATO forces in Europe: sea denial rather than sea control. Small patrol craft, frigates, and submarines armed with cruise missiles were an inexpensive means of performing that mission. It was the nature of the Soviet naval mission combined with a scarcity of resources that led to the development of Soviet cruise missiles.

In summary, the perceived delay by the U. S. Navy in developing the anti-ship cruise missile was no failure at all. Anti-ship cruise missiles were deployed to the fleet not long after the necessary components became available and when the Navy's mission required a strong anti-ship capability. It could be claimed, perhaps, that the aviators inappropriately retained sole claim to the shore bombardment mission from 1950 to 1967, but that claim overlooks the large strategic role of the submarine force and the inherent flexibility of naval aviation in shore bombardment missions. Surface Warfare

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[16] Nihart, "Harpoon," p. 23.

[17] K. Tsipis, "Cruise Missiles," Scientific American, vol. 236, no. 2 (February 1977), p. 20.

Officers have never demonstrated the need for a strategic role or the capacity for a conventional tactical role for cruisers and destroyers in projecting power ashore (beyond the range of naval gunfire).

## Cruise Missile Warfare: Where Navy Innovation Failed

The thesis of this paper is that the U. S. Navy developed cruise missiles for anti-ship and conventional shore bombardment missions when the circumstances of technology and perceived service mission were right. Nevertheless, there was a glaring failure in the Navy's organizational response to cruise missile technology. For nearly twenty years, the U. S. Navy systematically underestimated the capabilities of potentially hostile cruise missiles, and failed to take appropriate countermeasures. Specifically, the Navy failed to develop the cruise missile defenses that would be necessary in a conflict with Soviet naval forces or with the forces of her client states.

As noted above, a 1975 article described Harpoon as a 1975 response to a 1960 threat.[18] Harpoon alone, however, is an inadequate response unless U. S. naval commanders could assume that opposing forces will never have the opportunity to launch their missiles. U. S. anti-missile missiles are generally effective, but there is a substantial probability that any given incoming hostile missile will penetrate those defenses, especially when multiple missiles are inbound. Chaff, electronic countermeasures, and

[18] Nihart, "Harpoon," p. 22.

maneuver can also shake some proportion of incoming missiles, but not all. "Leakers" are a problem.[19]

The response of the Navy, in 1968, was to initiate the development of the close-in defense system, now know as the Vulcan Phalanx or the CIWS (Close In Weapon System).[20] This system reflects adaptation of technology to the in-depth, layered defense doctrine that the Navy has gradually developed over the past 40 years. However, the innovative process that produced CIWS was not initiated until 1968 and the system was not deployed until 1980, 20 years after the Soviet's deployed their Styx missile (see Table 1). In the interim, surface forces relied upon electronic warfare, maneuver, missiles and gunfire for defense.[21] Had the United States found itself engaged in conflict with the Soviet Union, losses to the U. S. fleet might have been heavy, especially if Soviet forces employed a surprise strike against U. S. carriers to initiate the conflict.[22] Fortunately, that window of vulnerability passed without Navy defenses being put to the test.

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[19] Breemer, "Why Close-In Defense?" National Defense, vol. 70, no. 2 (February 1986), p. 45; E. L. Hozee, "Missile Defense at Sea," Journal of Defense and Diplomacy, vol 4, no. 1 (January 1986), p. 43.

[20] N. Friedman, The Naval Institute Guide to World Naval Weapons Systems (Annapolis: Naval Institute Press, 1989), pp. 293-295.

[21] For a discussion of concepts of cruise missile defense in the mid-1970's, see W. J. Ruhe, "Cruise Missile: The Ship Killer," U. S. Naval Institute Proceedings, vol. 102, no. 5 (June 1976), p. 45.

[22] A. D. Zimm, "The First Salvo," U. S. Naval Institute Proceedings, vol. 111, no. 2 (February 1985), p. 47.

Curiously, Rear Admiral W. E. Meyer publicly described the U. S. Navy as a generation ahead of other navies in cruise missile defenses in 1976.[23] No doubt the Admiral was pleased with the progress his command, Naval Sea Systems, was making toward completion of new defensive systems. Although the Navy was ahead of others, it clearly started work on cruise missile defenses too late, and left the fleet perilously vulnerable to missile attack.

## Lessons for the Future

Alan Powell recently reviewed weaknesses in the innovation process for naval ships and, while his general observations are germane here, they will not be reiterated.[24] The following are issues that specifically derive from this study.

Anticipate Dissent. It is rare time when the members of a large organization share a common vision of the future. In the more common instance, when a variety of futures are envisioned by different members, some will inevitably prove better predictions than others. Everyone cannot be right. The failure to perceive accurately the shape of the future can be unrelated to the individual's expertise, stature, persuasiveness, or influence. Consider, for example, the following statement from Vannevar Bush, who was President Franklin D. Roosevelt's head of the Office of Scientific Research and Development during the Second World War:

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[23] W. E. Meyer, "Comment on 'Cruise Missile: The Ship Killer,'" U. S. Naval Institute Proceedings, vol. 102, no. 8 (August 1976), p. 94.

[24] A. Powell, "To Foster Innovation in Naval Ships," Naval Engineers Journal, vol. 94, no. 4 (April 1982), p. 253.

"Thus, a pilotless airplane could be made to fly smoothly thousands of miles in spite of buffeting and weather vicissitudes. It could be made to take off and land automatically. It could even be made to carry out its own navigation to a distant target, for example by using loran, and to drop its bombs there. By resort to extremes of mechanization it could even be made to fire its guns or other missiles at approaching enemy aircraft. All this without a crew aboard. All this could be done, and other features added, all at enormous expense for development and very large cost per unit. But it would not be worth doing."[25]

"One thing that was done as the war began was to build semi-conventional airplanes in this manner, usually with all the engines and gear, and a very considerable cost, to use as missiles. They never came into use. It was fairly evident at the outset that they would not. It requires a valuable target indeed, and strong presumption that it will be hit and destroyed by a missile, to throw away an entire expensive aircraft at every shot. We do not need to go into this fiasco in detail. It is an illustration of what can happen when military requirements are written by enthusiasts of little grasp . . ."[26]

The point is obvious enough: even as the Navy was developing the Regulus I cruise missile, the prominent and influential Vannevar Bush could see no future for cruise missiles. Bush had no personal stake in the matter; his careful, dispassionate analysis of the system's potential costs and benefits indicated to him that it was not worth pursuing. Well intentioned, thoughtful and intelligent people can be (and often are) wrong about the future. Bush was aware of this and stated emphatically, "I am not much of a prophet . . ."[27] Naval leaders must expect such dissent. Furthermore, it would be most wise not to stake the Navy's future on any one vision of the future or any particular weapon system.

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[25] V. Bush, Modern Arms and Free Men: A Discussion of the Role of Science in Preserving Democracy (New York: Simon and Schuster, 1949), pp. 80-81.

[26] V. Bush, Modern Arms, p. 76.

[27] V. Bush, Modern Arms, p. 2.

**The Value of Patience.** The innovation process requires time. Warfighters are understandably impatient, especially in times of conflict, to obtain new weapons that will surprise, demoralize, and defeat the enemy. Officials responsible for several cruise missile projects hurried the development of their new weapons (e.g., aerial torpedo, Project Option). However, the rush to deploy new technologies can have several unfortunate consequences. Decisions to move prematurely to operational evaluation might only lead to an unsatisfactory evaluation. Lawrence Sperry's 1918 aerial torpedo was inadequate for anti-ship missions, thus discouraging officers in BUORD, but his 1922 radio-controlled torpedo (developed for the Army!) could have been an effective anti-ship weapon. Indeed, Billy Mitchell wanted to employ aerial torpedoes in the famous bombing demonstration off New Jersey in 1923.[28] Project Option's TDR-1 assault drones were slow, large, and vulnerable to enemy fire. Even if suboptimal technologies survive operational evaluation, precipitous deployment might require the warfighters to forgo advanced technologies with valuable capabilities.

Often coupled with the warfighter's impatience is an inability of scientists and engineers to forecast the time necessary to complete R & D. As S. Sandler has remarked, "Rare, indeed unknown, is the innovator who concedes that his project will consume nearly a decade of resources before it can be put to effective use."[29] The salient problem is that development time cannot be predicted with any accuracy.

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[28] K. P. Werrell, The Evolution of the Cruise Missile (Maxwell Air Force Base: Air University Press, 1985), p. 23.

[29] S. Sandler, "Technology and the Military," U. S. Naval Institute Proceedings, vol. 98, no. 3 (March 1972), p. 59.

There is a natural tension between the need to deploy new technologies and the possibility of further improvement or additional capabilities with continued research and development.[30] Only the good judgement of responsible officials can determine when a system should be deployed. However, the history of cruise missile innovation suggests that Navy officials sometimes demonstrate poor judgement in rushing to deploy new systems.[31]

Stabilize Resources for Innovation. Scientists, engineers, and other specialists dedicated to innovation cannot function effectively in "feast or famine" environments. Innovation requires a stable, even nurturing environment. The Regulus II program, for example, could have been continued with only minimal financial backing, thus avoiding the "stop and start" pattern of cruise missile development in the years 1957-1967. Stability also allows project managers to keep teams of experienced personnel together.

Be Prepared for Failure. The large majority of Navy cruise missile programs never produced a weapon that was suitable for deployment. In most cases, the technology was simply not adequate for the task at hand (e.g., the aerial torpedo, Projects Fox, Dog, Option, Project Aphrodite, Rigel, Triton). In other instances, the need no longer existed by the time the missile was ready (e.g., Gorgon). Failure must be the expected outcome of most innovation efforts. Politicians, taxpayers, and Navy officials concerned about the

[30] E. Johns, "Perfect is the Enemy of Good Enough," U. S. Naval Institute Proceedings, vol. 114, no. 10 (October 1988), p. 37.

[31] The obvious example is Project Aphrodite, where the use of primitive, jury-rigged equipment led to the loss of American lives with no evident damage to the enemy.

careful use of public dollars must be prepared for failure.[32] Management must be prepared to persist when difficulties are encountered. Stanley Sandler has correctly observed that "For every successful Manhattan Project, there were several disastrous and expensive failures . . ."[33] However, the gains reaped from that project more than repaid the cost of those other failures. Technological progress defies simple accounting for the taxpayer, but the benefits of successful innovation are vital for the survival of the nation.

Protect the Zealots. New technologies are often viewed as a threat to older systems and the people who operate and manage them. Individuals who perceive their futures to be endangered by an innovation can (and have) engage in reprisals against zealots. Such reprisals are often subtle, involving actions short of an official organizational response (e.g., future assignments). Zealots are an important part of the innovation process, and their reasonable behavior should be protected by the Navy. Unreasonable behavior, on the other hand, need not be tolerated.[34] Support for zealots could either involve active commitment (vertical alliances) or, at minimum, a studied neutrality, ensuring only that all parties to a professional controversy are treated fairly. Officers who successfully promote technology that eventually proves valuable should be rewarded for their good judgement, foresight, and commitment. Zealots for unsuccessfully innovations should be thanked for their interest and redirected to other

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[32] Alan Powell reminds us that innovative failures are not (necessarily!) managerial or personal failures. Management must be prepared to defend unsuccessful innovators or see the willingness to innovate stifled. See A. Powell, "Foster Innovation," p. 253.

[33] S. Sandler, "Technology," p. 56.

[34] The actions of General William "Billy" Mitchell that led to his eventual court-martial and resignation seem to constitute unreasonable activities.

endeavors. Vigilance and good judgement on the part of flag officers is critical to protect and encourage zealots.

In this regard, successful innovation also depends upon vertical alliances with Navy flag officers. Flag officers share a responsibility to become involved in instances where the technology might prove useful in the future.

Avoid Organizational Myopia. Earlier in this chapter, the relationship between missions and technology was cited as a critical element in the development of technology. That relationship is dynamic, and varies in response to the international and national military environment. Naval leaders must avoid focussing on current roles and missions and, instead, look to future roles and missions. For example, the failure of naval leaders to consider the future nature of war at sea in 1950 led to the complete failure to develop tactical anti-ship cruise missiles. Had these leaders foreseen the emergence of a great fleet to oppose the United States Navy, the course of Navy innovation might have been quite different. Instead, organizational myopia eliminated opportunities for innovation. Forehandedness has long been the mark of the successful naval officer; foresight must be the mark of the future naval leader.

## The Value of Stability

Common wisdom among politicians, journalists, and even the general population holds that the U. S. Navy is a conservative, even stale[35] organization that, like all

[35] Pejorative adjectives such as "crusty," "hidebound," or "reactionary," are applied to the Navy with some frequency in the press and the halls of the federal government, partly as a result of the service's historically slow reaction to emerging social issues.

military services, is constantly preparing to fight the last war. Students of strategy and other military issues have created a cottage industry of analysts who are regularly surprised to discover that change usually comes slowly in the military. These scholars often overlook the obvious; military organizations such as the U. S. Navy have survived and functioned effectively (if not efficiently) in the midst of change for more than two centuries. Many European armed services have much longer histories. If they are so resistant to change, how can these organizations survive and flourish for centuries?

Like the pessimist whose glass is always half empty, critics of military innovation have failed to appreciate the value of stability in large organizations. Stability has many virtues, but Posen has identified the most compelling justification.[36] Organizations in flux are vulnerable; military leaders will invariable seek to minimize the necessary change in order to lessen that vulnerability. It is also important to remember that change is difficult; it requires energy and effort for education and training, let alone the cost of new technology. Wise leaders will seek to eliminate unnecessary change or upheaval that brings only marginal value. Furthermore, the Navy has a demonstrated capacity for change when there is a clear and immediate need. There is a delicate balance between the stability that organizations require to be effective and the need to remain at the forefront of technological innovation. As the Gulf War demonstrated, the U. S. Navy has succeeded thus far in maintaining that balance.

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[36] B. R. Posen, The Sources of Military Doctrine: France, Britain, and Germany Between the World Wars (Ithaca: Cornell University Press, 1984), pp. 30-31.

## CHAPTER VI

## CONCLUSIONS

The U. S. Navy has been faulted by critics within and outside the military for responding too slowly to advances in technology. These criticisms have spawned a host of studies purporting to document the Navy's putative shortcomings in technological innovation. The history of innovation within one field of technological endeavor, cruise missiles, contrasts with prior claims that the Navy failed to pursue promising missile technologies as a result of intraservice rivalry. That history demonstrates an active commitment to innovation that sometimes included as many as four simultaneous programs and stretched over more than 50 years. Many of those programs were promoted and managed by aviators, the very group that supposedly suppressed missile technology. Those programs led to the operational evaluation of more than nine different missiles and the deployment of Regulus I, Harpoon, and Tomahawk.[1] The Navy meets the ultimate criterion for success in innovation: the systems were available for use when they were needed: not too soon, not too late.

Past success does not guarantee similar results in the future. Naval leaders must encourage innovation when possible. The innovative process can be facilitated by guarding against several common, recurring problems. The innovation process will

[1] The actual number of missiles evaluated was actually larger because some projects, like the Gorgon missile, included several different missiles.

function most effectively when resources are stable (or at least predictable). The process can be accelerated by the infusion of resources but should not be rushed. Prematurely rushing into operational evaluation or deployment often leads to the delivery of ineffective systems. Innovation often yields failure, and managers must expect and prepare for that eventuality. Officers who actively promote new technologies, the zealots who proselytize for a new vision of warfare, must be protected from retribution and rewarded if their visions come to pass. Finally, naval leaders must consider the form of future warfare in making their decisions regarding innovation. Decisions predicated on today's conditions and warfare needs will inevitably prove short-sighted.

The history of naval cruise missile innovation, coupled with the understanding that innovation is a process, not a result, yields some useful insights into strategies for managing innovation in the future. Innovation should be directed and controlled by a sequence of decisions.[2] The standards to justify proceeding to subsequent phases of innovation should be increasingly tough, with the highest standard required for the deployment of a new technology. Managers should be encouraged to risk modest (by government standards) funds and support on new concepts and preliminary R & D. Intensive R & D and Operational Evaluation ought to entail only moderate risk, and deployment should bring only minimal risk. In this scenario, the balance between risk and financial commitment shifts from high risk/low cost to low risk/high cost as the innovation process proceeds.

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[2] Obviously, this is how innovation is managed today, as projects pass the various DSARC milestones. See the Joint Staff Officers Guide 1993 (Washington, D.C: U. S. Government Printing Office, 1993), pp. 5-19-23.

Naval warfare of the future will differ from past wars in both predictable and unpredictable ways. The technological innovations necessary to cope with the changing nature of war at sea will undoubtedly challenge future naval leaders. The nation will be well served if those future leaders meet the new challenges as well the officers of the past fifty years.

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